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SURGERY OF THE HIP JOINT FROM THE PHYSIOLOGIC ASPECT*

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THE practical application of physiologic principles in orthopedic surgery is by no means confined to the hip joint, but in no other joint is the physiology of bone so well exemplified. This is undoubtedly due to many factors, of which the following will be briefly discussed: (1) anatomy, (2) embryology, (3) bone structure, and (4) circulation.

ANATOMY

The hip is a ball-and-socket or enarthroidal joint, formed by a hemispheric socket in the innominate bone and by the head of the femur. The anterior portion of the acetabulum slopes anteriorly and medially, and the posterior portion slopes posteriorly. The circular, fibrocartilaginous cotyloid ligament which surrounds the rim of the acetabulum adds considerably to its depth. The wall of the acetabulum is lined with a broad band of articular cartilage, while the floor is formed by the large, nonarticulating acetabular fossa, which contains fat and synovia. The defect in the bony rim of the anterior inferior portion of the acetabulum, the acetabular notch, is completed by the transverse ligament. The femoral head is globular in shape and is covered by cartilage, except for a small, pitlike depression on the medial aspect just below the summit—the fovea capitis.

At birth, the epiphysis approximates the diaphysis in the horizontal plane. As growth proceeds, the angle of the neck with the shaft decreases, and the plane of the epiphysis assumes a more vertical position. By the age of 11 years, force from above downward places a definite shearing stress upon the epiphysis itself, and, since this structure has little support from below, a partial or complete separation can more easily occur from trauma or a pathologic process.

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The head and neck of the femur form an angle of approximately 145 degrees with the femoral shaft in children; this gradually decreases, reaching 135 degrees in young adults, and 125 to 120 degrees in elderly individuals. There is, normally, an anteversion of the neck on the shaft of the femur of approximately 25 degrees. Thus, the entire weight of the body is received on an oblique axis, rendering this area particularly susceptible to physical forces. The relation of the head and neck to the acetabulum is much the same as that of an axle to a wheel.

The capsule is attached to the acetabulum, cotyloid ligament, and transverse ligament; distally, the capsule is fixed at the anterior intertrochanteric line anteriorly, and at the middle of the femoral neck posteriorly. This explains the fact that fractures of the lateral portion of the femoral neck heal more readily than central or subcapital fractures. The head and greater portion of the neck of the femur are therefore lying within the joint cavity and are bathed by synovial fluid. This point is important, since infection within the metaphysis may readily invade the joint, and vice versa. The capital epiphysis, lying wholly within the joint, is readily involved in intra-articular infection. The synovial fluid, moreover, inhibits the formation of hematomas, a vital factor in healing of fractures of the femoral neck. Finally, the periosteum of the femoral neck is scant, definitely minimizing the formation of periosteal callus in fractures of this region.

The capsule is reinforced by three powerful ligaments which, with the aid of negative pressure, maintain the relationship of the femoral head and acetabulum. The strongest of these is the iliofemoral or Y-ligament of Bigelow, which reinforces the anterior portion of the joint. The pubocapsular and ischiocapsular ligaments support the posterior and inferior aspects. Points of weakness are present at the junction of the ischiocapsular and pubocapsular ligaments and between the iliofemoral and pubocapsular ligaments; this partially accounts for the preponderance of dislocations wherein the capsule is ruptured posteriorly and inferiorly. The ligamentum teres, which passes from the cotyloid cavity to the fovea capitis of the femoral head, functions chiefly in the transmission of blood supply and plays little part in the mechanical support of the hip.

The hip is surrounded by powerful muscles, concerned chiefly with the mobility of the hip and maintenance of the head within the acetabulum. With impairment of the capsule from stretching or relaxation, however, the action of the muscles may be a predominant factor in producing paralytic or pathologic dislocation. Relaxation of the capsule is commonly observed in association with extensive paralysis about the hip joint; distention is usually induced by pyogenic infection. In acute affections of the hip, the joint is maintained in a position of flexion, usually, in the early stages of the disease, associ-

ated with varying degrees of abduction and external rotation. After destructive changes take place, the position is flexion, adduction, and internal rotation. In the latter position the bony support for the head is minimal; this factor, in addition to impairment of the capsule from distention and stretching, predisposes posterior dislocation. The Trendelenburg sign, i.e., sagging of the opposite side of the pelvis on standing on the affected leg, indicates abductor inefficiency. Weakness of these muscles may arise (1) from inadequate superior support of the femoral head, as in congenital dislocation of the hip; (2) from coxa vara, whether of congenital origin or induced by trauma or disease; or (3) from paralysis of the gluteus medius muscles.

The normal movements of the hip joint are flexion, abduction, adduction, extension, hyperextension, and rotation, within a definite range. Movement of the extremity beyond the normal range of the hip joint is secured by compensatory movement of the spine and pelvis.

EMBRYOLOGY

The formation of the femur and innominate bone from the skeletal anlage begins at the 1 to 2 cm. stage, or about the fourth or fifth week of fetal life. A joint cleft appears and gradually enlarges until, by the ninth week, the differentiation is complete. The femoral head is at first rectangular in form and without a neck, and gradually is pushed away from the acetabulum by a cervical bud. The acetabulum is formed by a tripartite base from the primitive ilium, ischium, and pubis. Development proceeds with the formation of the capsule, ligaments, and muscles. The newborn child has a relatively large spherical head with an underdeveloped acetabulum. During the first three years of life, the head lies in the upper part of the socket; by the end of this period formation of the acetabular roof is complete and the head is placed in the center of the acetabulum.

Abnormal evolutionary changes are best illustrated in congenital dislocation of the hip. The head of the femur may be flattened, and the anteversion or normal anterior deviation of the neck greatly increased. The acetabulum, which is formed from the ilium, ischium, and pubis, may be oval or triangular, and entirely without the very important upper support. The capsule is contracted near the head, forming a so-called hourglass constriction, through which the ligamentum teres passes. The capsular structures are the principal support, and after one or two years of weight-bearing may become extremely hypertrophic. This process may be observed in varying degrees without an actual dislocation. The underlying disability arises from the abnormality in shape of the acetabulum. If flat and devoid of superior support, the articulation is unstable and weight is improperly distributed; this leads to a reaction in the entire joint, with secondary changes in the head and neck.

An abnormality in any one of the three bones from which the acetabulum is formed will have a definite effect upon the other two. To illustrate, as Murk Jansen pointed out, ischium varum, or medial deviation of the ischiopubic portion of the acetabulum, is often associated with secondary changes in the head and neck of the femur and consequent coxa plana, or so-called Legg-Perthe's disease.

Static relations of the lower extremity also may give rise to decided changes in the hip, as well as other joints, as demonstrated by Preiser. For example, genu valgum, or knock-knee, may so change the weight-bearing areas in the hip that the articular surfaces may become involved in a secondary reaction from excessive and continuous weight on one point. In anteversion of the neck the hip is held in external rotation and the weight-bearing articular surface is materially restricted. This mechanism is similar to the wear of an automobile tire when the alignment is irregular. In operative procedures these factors must receive due consideration, and anatomic alignment must be restored if normal function is to be expected.

BONE STRUCTURE

There are three theories regarding the evolution of normal bone structure: (1) *functional adaptation*, as advanced by Culman and Meyer and later expounded by Wolff in his celebrated law, which Murphy freely translated, "As a tree is bent, so will it grow"; (2) *that form and structure are due chiefly to pressure*, as suggested by Murk Jansen; and (3) *inherent growth*.

In 1866 Culman and Meyer pointed out that the development of bone is due to both pressure and stress, as demonstrated by the arrangement of the trabeculae in the neck and head of the femur. As the trabeculae in the neck cross, an angle is formed which is filled with spongy bone having little tensile strength; as age advances, the cancellous bone is replaced by fat. This angle was first described in 1838 by Ward, an English anatomist. Culman and Meyer regarded this arrangement as an effort of nature to conform to mechanical laws, and compared it to the trajectories of stress and pressure in a crane. Murk Jansen observed that the lines of stress in a crane cross at a right angle, while those in the neck of the femur form a more acute angle; he, therefore, attributed the molding of the bone to pressure. Undoubtedly, there is also an hereditary or inherent factor in the germ plasm or cells, as normal form may be produced without either pressure or stress. This fact is demonstrated in certain congenital anomalies. Regardless of theory, the mechanical arrangement is the practical factor from a surgical aspect.

In children the head of the femur is composed chiefly of cartilage with a bony nucleus; after fusion of the epiphysis, the bone of the

head becomes dense and hard and is supported by strong trabeculae. The neck of the femur in children is pliable; this accounts for the fact that fracture of the neck is seldom observed in children. When fracture does occur, the location is, with few exceptions, at the base of the neck or the junction with the shaft. In adults the bone of the femoral neck is more brittle, and quite strong until the activity of the sexual glands is diminished. Cessation of function of these glands, particularly of the ovary, may be responsible for decalcification, with a decrease in the angle of the neck. Proof of this relationship is observed in roentgenograms of young women following artificial menopause by oophorectomy.

Bone atrophy, a most important consideration in surgery of the hip joint, may be induced by systemic agents, as dietetic, chemical, or endocrine imbalance, but for the purposes of this discussion only two types need be mentioned: atrophy of disuse and osteoporosis. In the atrophy of disuse the size and resistance of the bone structure are diminished; in osteoporosis the process is a pathologic reaction to irritation from trauma or disease. In any surgical procedure osteoporosis should be eliminated, if possible, prior to operation.

The atrophy of old age apparently is a combination of the atrophy of disuse and deficiency of the sexual glands. Activity, however, is a factor in maintaining the normal structure of bone. This is proved by the fact that in men, who lead more active lives than women, the bone structure is comparatively stronger. Further, in aged individuals the status of the bone structure is commensurate to a degree with activity.

CIRCULATION

Circulation is undoubtedly the most vital factor in osteogenesis. If the circulation is ample, healing will occur within a normal period of time. If the circulation is markedly increased, decalcification or absorption of the bone will take place. If the circulation is diminished, bone formation will be retarded, and hard, dense bone will be formed; this type is of low quality and bears the same relation to normal bone that scar tissue bears to normal soft tissue. If the blood supply is obliterated from any cause, the area supplied will die and become a sequestrum.

The head of the femur is supplied by capsular, periosteal, and interosseous vessels, the two of greatest importance being the posterior capsular branch of the internal circumflex artery and the artery of the ligamentum teres, as so ably demonstrated by Wolcott. In children, prior to the change in the plane of the epiphysis, the artery of the ligamentum teres is the chief source of blood supply; whereas, in adults the posterior capsular artery becomes the principal source of supply. With old age, the lumen of the artery of the ligamentum teres

may decrease and even become entirely occluded, restricting the blood supply from this source. This, however, is not true in every case, as we have repeatedly demonstrated the patency of the artery after excision of the head in old people.

THE PRACTICAL APPLICATION OF PHYSIOLOGIC PRINCIPLES

The practical application of physiologic principles can best be illustrated by considering some of the various affections for which surgery is indicated. Operative measures should be directed toward maintenance of adequate superior support for the femur and, if possible, the length of the femur, a smoothly articulating joint surface, and effective muscle action.

In all operations upon the hip, conservation of the circulation is a major requisite. The capsule should always be incised at the junction with the acetabulum, or longitudinally and parallel with the neck of the femur, or both. Care must be exercised to avoid injury to the posterior capsular artery, since the other important source of blood supply, the ligamentum teres, is frequently severed. In adults a large portion of the neck is normally within the capsule and is invested only by synovial membrane; after an inflammatory lesion, however, soft tissue may become adherent throughout the neck, providing an appreciable amount of blood. Stripping of this soft tissue should be limited to the smallest extent compatible with the mechanics of the operative procedure. In children the inferior portion of the capsule is attached to the neck as far as the epiphysis and should not be divided, since this is also a minor source of blood supply.

The blood supply can best be conserved by the anterior iliofemoral approach, as popularized by Smith-Petersen. The upper limb of this incision parallels the anterior portion of the iliac crest, and the lower limb extends between the tensor fasciae femoris and sartorius muscles. This approach permits wide exposure of the hip joint without damage to any part of the major blood supply to the femoral head and neck and the acetabulum, by dissection in anatomic planes and stripping of the anterior portion of the gluteal muscles subperiosteally from the ilium. If extensive exposure of the acetabulum is desired, the muscular attachments may be stripped from the inner aspect of the ilium and all structures severed to the anterior iliac crest. In other approaches, such as the Kocher U-shaped incision, or the goblet incision, the posterior capsular artery is frequently severed, leading to extensive degeneration of the head and neck of the femur.

Loss of support to the upper extremity of the femur, a serious, yet probably the most common disability, may be caused by a variety of affections, such as congenital dislocation of the hip, ununited fractures of the neck of the femur, pathologic dislocations incident to destructive processes, and tabes dorsalis. For this condition, two types of operations are suitable: (1) those whereby an actual osseous sup-

port is created, and (2) those whereby weight is thrown directly upon the lateral aspect of the pelvis, or a combined upper and pelvic support. If the defect is in the superior wall of the acetabulum, as in congenital dislocation of the hip and changes secondary to poliomyelitis, either a new acetabulum may be formed by excavation, or, upper support may be provided by reflection of a shelf of bone outward from the ilium, or these methods may be combined. Excavation of a new acetabulum is more satisfactory if the normal plane of the joint can be secured; mere extension of the roof to a higher level materially improves the mechanics but does not restore normal muscle balance or function.

Fig. 1.—Bilateral congenital dislocation of hips, showing shallow, sloping acetabulum.

The normal length of the extremity may frequently be restored by traction, but often the structures are so firmly fixed that the head can be returned to the level of the acetabulum only by severance of the soft structures at open operation. Reduction must not only be accomplished, but must be maintained. In poliomyelitis, reduction may often be effected by the patient with little effort, the only problem being retention after reduction; whereas, in congenital dislocation of the hip reduction is often difficult.

When the upper extremity of the femur cannot be brought down to the level of the acetabulum, two types of operations may be employed. These can best be illustrated by their application to two conditions: congenital dislocation of the hip and old fractures of the neck of the femur with complete absorption of the neck. In the former the operative measures described above are employed. Either a shelf is constructed by flaps and grafts from the ilium and tibia, or a new acetabulum is made by excavation. The greatest care must be taken to bring the femur well forward and in line with the acetabulum, or even anterior thereto; otherwise, there will be serious imbalance, with Trendelenburg's sign markedly positive, and a typical backward lurching gait in a compensatory effort to restore muscle balance and weight distribution.

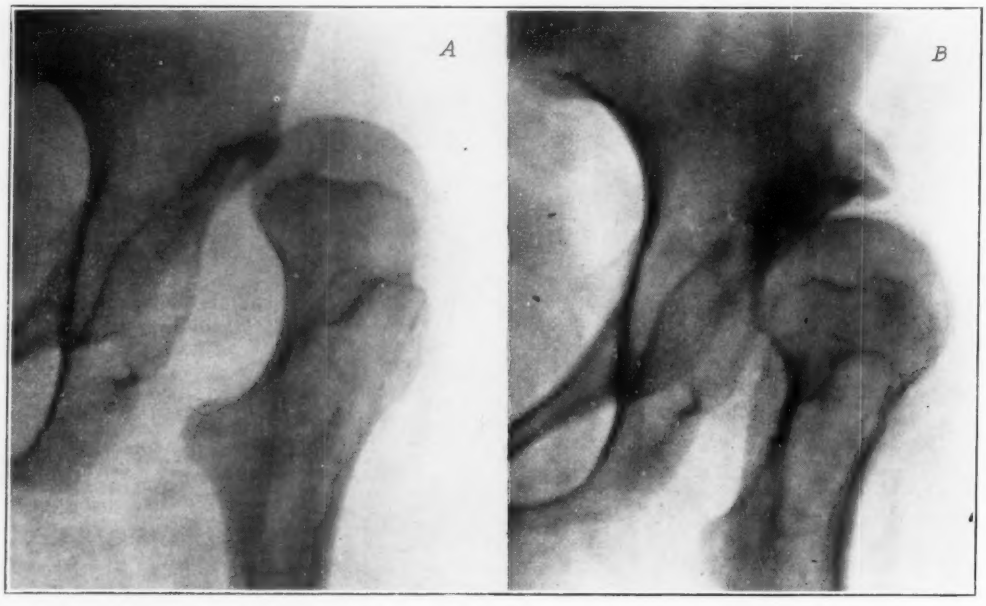

Fig. 2.—Paralytic dislocation of hip before and after shelf operation. Note shallow acetabulum with loss of superior support in preoperative roentgenogram.

Weight-bearing alignment may also be restored by subtrochanteric osteotomy, or osteotomy at the level of the tuberosity of the ischium. In the Lorenz procedure for congenital dislocation of the hip the osteotomy is performed at the level of the lower border of the acetabulum, the lower fragment being displaced medially. This provides support directly to the upper extremity of the femur in the acetabulum and, indirectly, to the lateral aspect of the pelvis. The Schanz osteotomy, at the level of the tuberosity of the ischium, results in medial angulation of the proximal fragment and allows the pelvis to rest against the oblique upper fragment on weight-bearing. These procedures, according to Putti, are not advisable until practically full

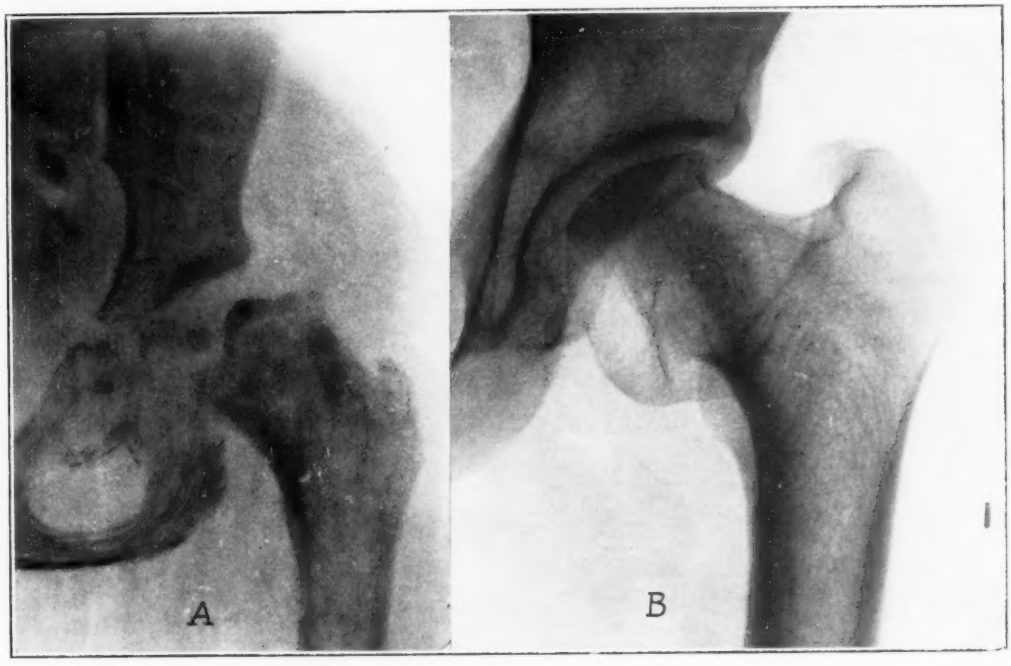

Fig. 3.—Coxa plana (Legg-Perthe's disease): stage of fragmentation in 1913, and residual coxa vara in 1929. Recent physical examination showed excellent function.

Fig. 4.—End result in coxa plana; excellent function of hip fifteen years later.

growth is attained. I am in accord with this opinion, as the element of growth obviously may change relationships.

In *coxa plana,* or Legg-Perthe-Calve's disease, definite changes are seen in the femoral head which are probably the result of circulatory impairment. This affection is most frequently observed in children between the ages of 5 and 9 years. The first stage is that of condensation; in the roentgenogram the capital epiphysis is more dense than the surrounding bone. Microscopic examination by several authors in a small series of cases has revealed aseptic necrosis of the head. The next stage is that of fragmentation, wherein tonguelike processes of granulation tissue enter the epiphysis in an attempt at organization. In the roentgenogram the epiphysis consists of two or

Fig. 5.—Old slipped upper femoral epiphysis, sixteen years later.

more fragments with alternating areas of condensation and rarefaction. During this stage, when bone is being absorbed by invading granulation tissue, the epiphysis is most vulnerable to mechanical forces, such as weight-bearing. Finally, the capital epiphysis undergoes a stage of healing, being entirely replaced by new bone and assuming a permanent fixed contour. If weight-bearing is prohibited, this evolutionary process may at times terminate in almost complete restoration of contour and normal function. If not properly treated, however, the femoral head may hypertrophy and the neck may become thick and short, leading to coxa malum.

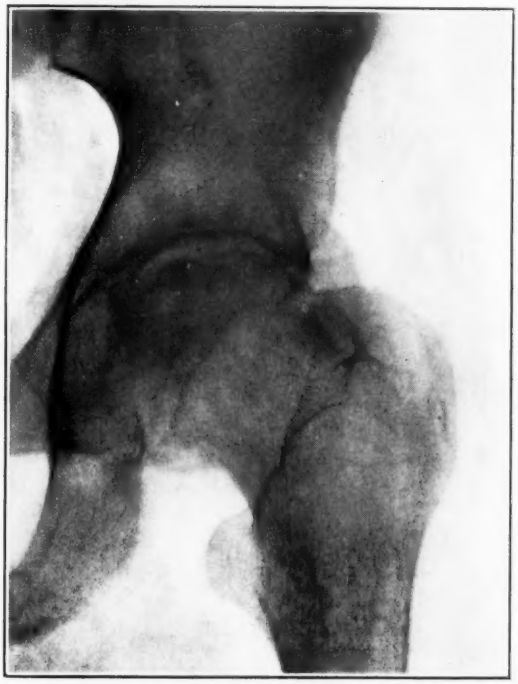

Fig. 6.—Old slipped upper femoral epiphysis; extensive degeneration of joint surface, with apparent narrowing of joint space and disability; two years later.

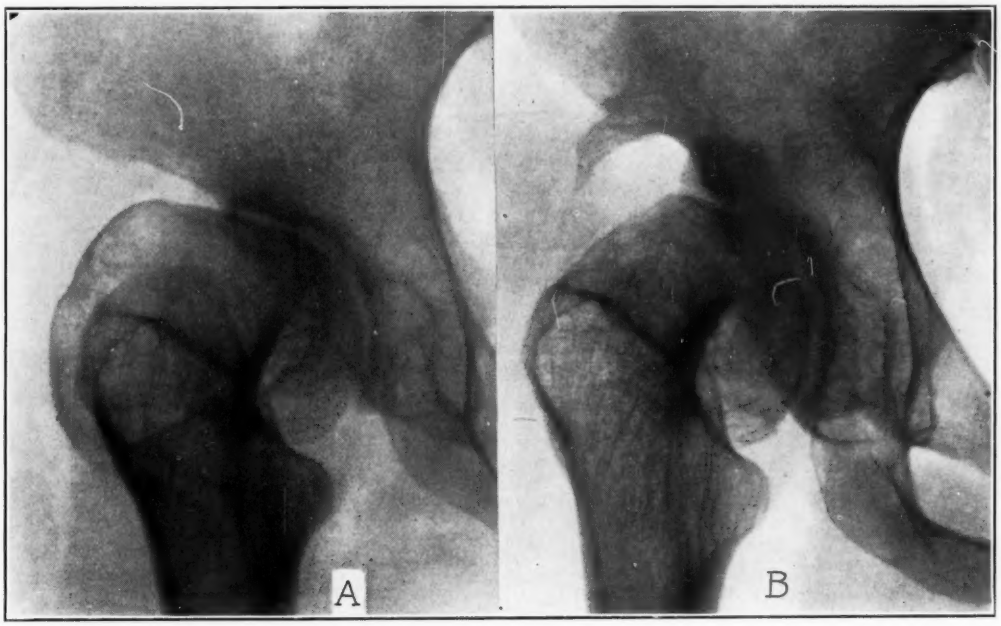

Fig. 7.—Old slipped upper femoral epiphysis with coxa vara; end result following reconstruction and shelf operation.

Epiphyseal separation occurs most commonly in children between the ages of 11 and 14 years. At this time the epiphysis has become more oblique, allowing greater stress at the epiphyseal cartilage on weight-bearing during the most active period of bone growth. The actual separation takes place in the metaphysis adjacent to the epiphysis. If the patient is observed soon after the separation (this is usually not the case), the femoral head may be replaced in its normal position and held by either a cast or internal fixation. In neglected cases, however, epiphyseal coxa vara is present. This malposition cannot be broken up by forcible methods, but requires osteotomy and anatomic replacement. When the condition has persisted for years, degenerative changes in the femoral head and neck, similar to those found in coxa plana, are observed.

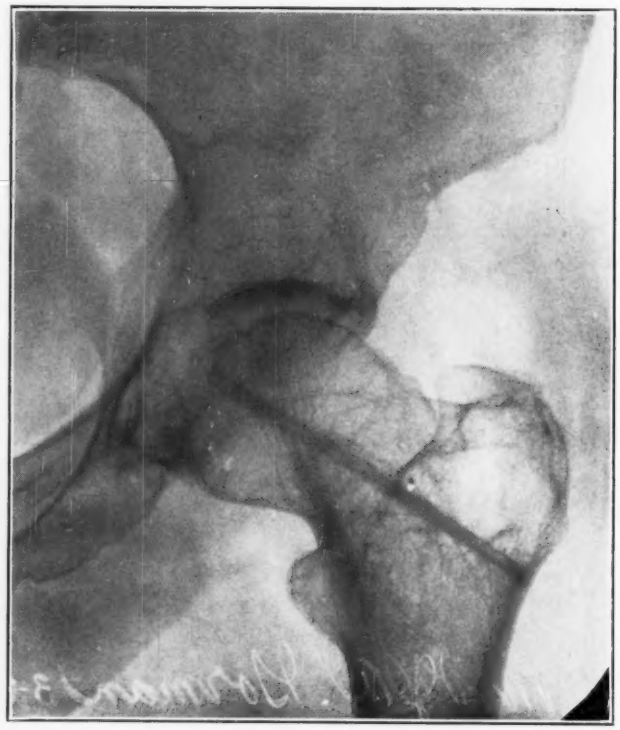

Fig. 8.—Fracture of neck of femur; twenty-three years later end result following bone graft with probable substitution by new bone.

In *fractures of the neck of the femur* the effect of the blood supply is well demonstrated. If the supply from the ligamentum teres is ample, the head will remain alive and will participate in the production of callus; osteogenesis, however, is always deficient. If the blood supply is inadequate, the head becomes necrotic en masse or in part. In many cases the blood supply is adequate to prevent necrosis of the head, but not to produce callus. A nonviable head is a sequestrum and maintains the same density as at the time of fracture, in contrast

to the surrounding bone of the pelvis and distal fragment, which undergoes regional atrophy. Similar changes will occur when the blood supply is just sufficient to keep the head alive; in this event the viability of the head cannot be determined by roentgenograms alone.

In *fresh fractures* of the femoral neck maintenance of the corrected position by internal fixation is more successful than by any other method; not only is close apposition secured, facilitating the invasion of new bone along the line of fracture, but shearing stress is eliminated and functional use of the limb promoted. Cast fixation, on the contrary, does not guarantee the integrity of the apposing fragments, eliminate shearing force, or allow movement of other joints of the affected extremity. Whatever the type of fixation, at least six months should elapse before weight-bearing is permitted, and some kind of apparatus should be employed for a much longer period, since callus in this region may remain pliable for a long time and shearing force from weight-bearing and muscle pull may give rise to separation of the fragments and nonunion.

In *ununited fractures* of the neck of the femur reconstructive measures may be undertaken to restore satisfactory weight-bearing. The procedure must be planned to meet individual requirements; i.e., according to the status of the femoral head, the age, general condition, and economic status of the patient, as well as his future functional requirements.

In younger, active individuals anatomic reduction may be secured by freshening of the fracture site and internal fixation by means of nails, pins, or a bone graft. Or, some type of reconstruction may be carried out, such as the Brackett operation, consisting of placing of the femoral head on the denuded neck; the Whitman reconstruction, wherein the femoral neck articulates with the acetabulum; the Colonna procedure, in which the femoral head is removed and the greater trochanter placed within the acetabulum; or the Albee operation.

In older, more debilitated patients who are poor surgical risks, the simpler palliative measure of osteotomy, which insures a satisfactory weight-bearing limb with a moderate decrease in the range of motion, is the method of choice. Osteotomy of the femoral shaft is performed at the level of the lesser trochanter and the shaft is placed beneath the femoral head and fracture site. Frequently, because of the elimination of shearing stress, the fracture will unite following this procedure.

The effect of the blood supply is also well illustrated in *traumatic dislocation*. After early reduction, the structure of the head of the femur is, in many cases, normal, although we know that the ligamentum teres is always ruptured; in other cases the head disintegrates, presumably from interruption of the blood supply through the posterior capsular artery.

In old unreduced dislocations the head usually retains its normal density and contour. This may be due to the fact that the posterior capsular artery is not ruptured or that the numerous blood vessels from the surrounding soft tissues rapidly invade the head, preventing

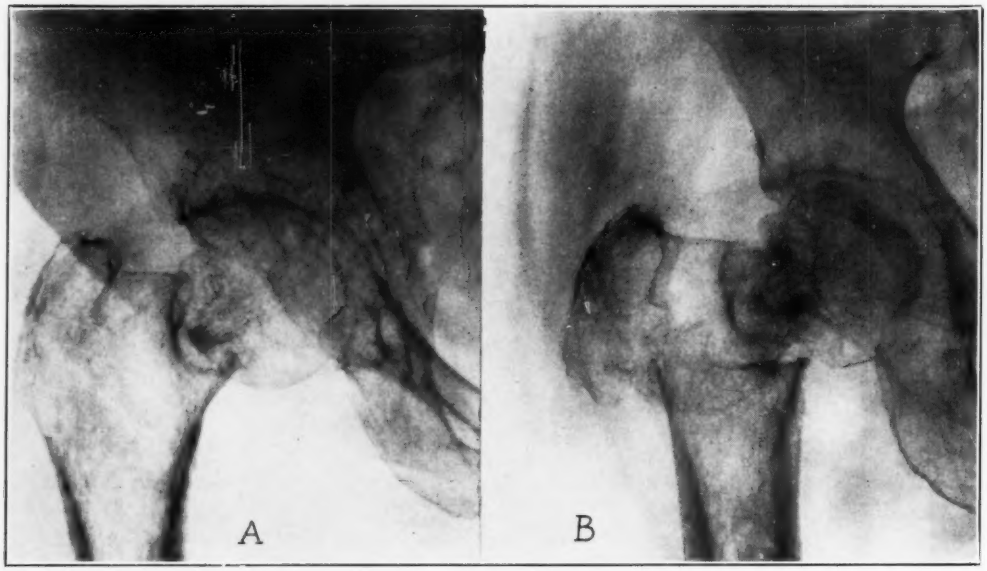

Fig. 9.—Ununited fracture of neck of femur; bone united following osteotomy at level of lower border of acetabulum.

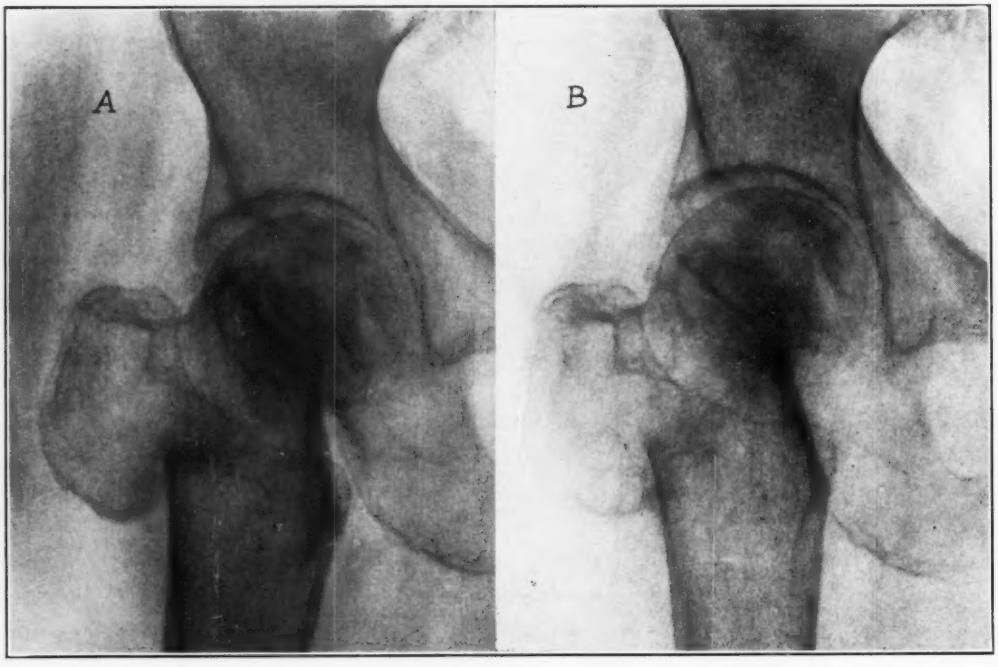

Fig. 10.—Ununited fracture of neck of femur following osteotomy at level of lesser trochanter; solid union head and neck four months later.

necrosis. Within two or three weeks after dislocation, the cartilage of the head undergoes degeneration and may become detached en masse; this may be caused by the loss of the action of the synovial fluid, which is derived indirectly from the circulation. In such cases, therefore, restoration of normal function is exceedingly rare after reduction.

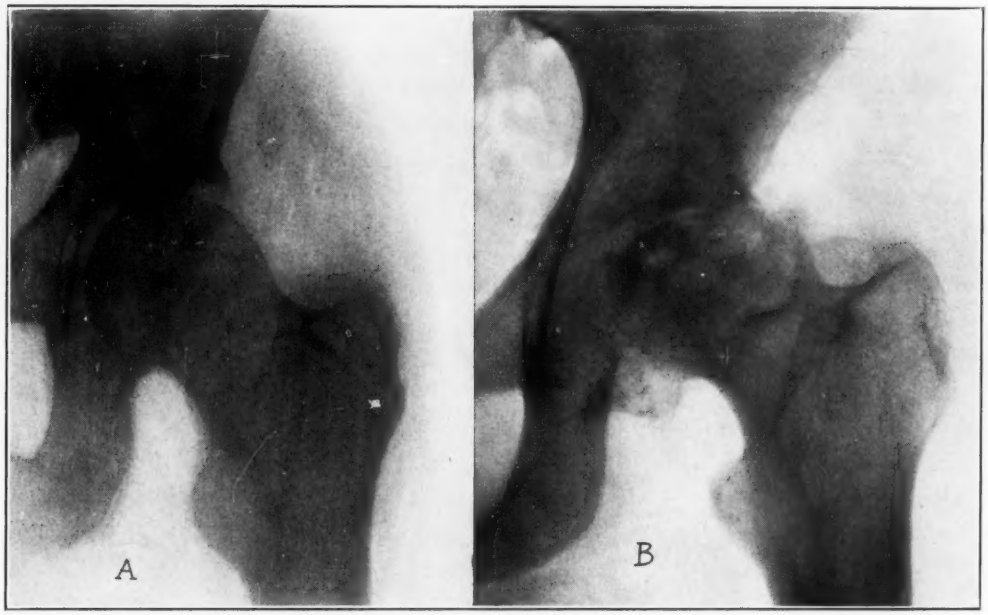

Fig. 11.—*A*, Traumatic dislocation of head of femur; apparently excellent result following operation. *B*, Traumatic dislocation of head of femur; later changes in the head due to aseptic necrosis.

In *acute pyogenic infections* of the hip joint the reaction varies according to the age of the individual. In infancy a pyogenic infection involving the epiphysis may so rapidly disseminate through the joint that the original site of invasion cannot be determined. On the contrary, in complete pathologic dislocation without destruction of the epiphysis, one may assume that the epiphysis is not involved and the process is an acute infection of the joint proper. Since the capsule envelops not only the epiphysis, but a large portion of the neck as well, invasion of both is not uncommon, and osteomyelitis and epiphyseal separation frequently ensue. Distention of the capsule from pyogenic exudate often causes complete dislocation of the hip in children; the younger the child, the more likely the dislocation. If dislocation is discovered at once, reduction accomplished, and efficient drainage instituted, a surprisingly satisfactory contour and relationship can often be restored; delayed reduction causes such extensive changes in the bone and surrounding soft structures that permanent disability may be anticipated.

In adults, as in children, the capsule encloses a large portion of the neck of the femur; infection, however, is usually confined to the joint proper, the bone of the neck being more resistant to infection. Dislocation occurs only when the process advances and destroys the roof of the acetabulum or a large portion of the head, or both.

In children the epiphysis frequently becomes necrotic, since the blood supply is greatly diminished through impairment of the ligamentum teres. The older the child, the greater the likelihood of death of the head without restoration. After the age of 12 years the head of the bone practically always dies, becomes a sequestrum and separates, eventually necessitating excision in order to induce healing.

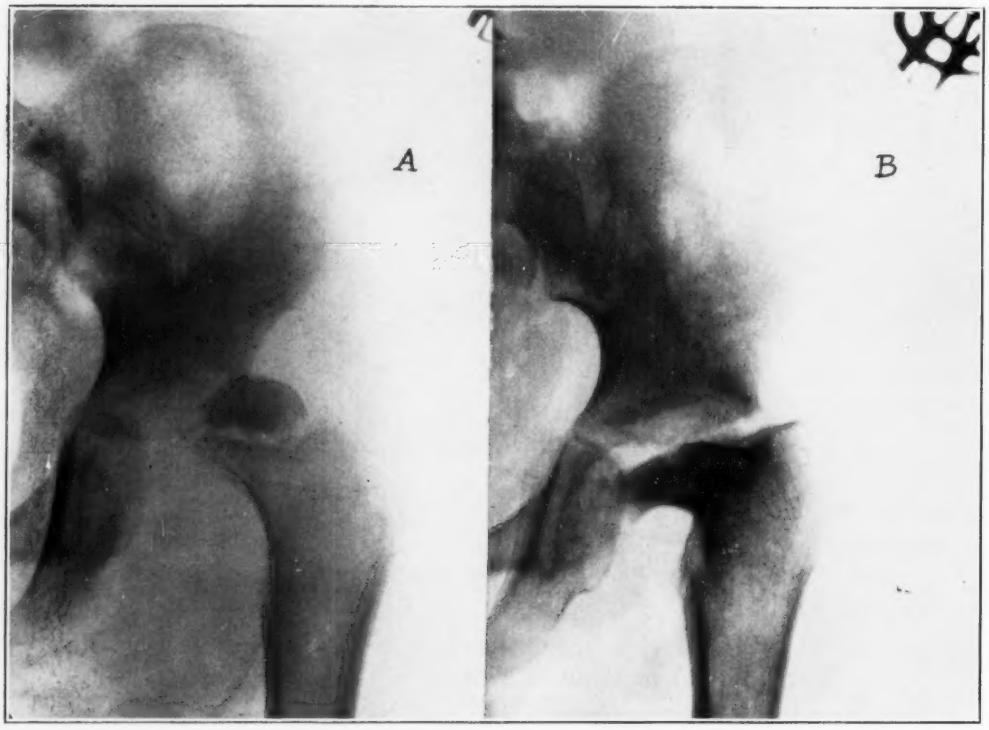

Fig. 12.—Acute infectious arthritis of hip with dislocation and necrosis of head of femur; end result showing extensive disintegration of head and neck.

This is due, not only to the involvement of the epiphysis in a virulent pyogenic infection and impairment of the circulation, but also to the change in the declination of the plane of the epiphysis as age advances, and the consequent shearing action. In younger children this feature is not present.

Monarticular osteoarthritis of the hip is characterized by hypertrophic and proliferative changes in both the head of the femur and in the acetabulum. Cysts are formed in the head of the femur from impairment of the circulation. The synovial membrane is often atrophic and scarred. Osteoarthritis may result from trauma or from degenerative changes in the head following slipped epiphysis and coxa plana, or

those acompanying old age incident to a previous infection of the hip joint, or from altered static relations in the joints of the lower extremity.

Four types of operations are commonly employed for osteoarthritis of the hip: (1) excision of osteophytes from the head or acetabulum, (2) reconstruction, (3) subtrochanteric osteotomy, and (4) fusion.

(1) Operations to restore the head to normal size and dimension are rarely satisfactory on account of the poor quality of the bone. Excision of the anterior wall of the acetabulum, or acetabuloplasty (Smith-Petersen), which permits free play of the head, gives a much better prospect of success. (2) Reconstruction consists of excision of the head and possibly of the neck, thereby producing an articulation between the acetabulum and the neck or trochanter. The abductor muscles, with or without their bony insertions, are attached to the trochanter at a lower level. This will usually permit a fair degree of motion but is far from satisfactory from the standpoint of endurance. (3) Subtrochanteric osteotomy, displacement of the fragments medially, and rotation of the

Fig. 13.—Osteomyelitis of ilium with secondary invasion of the hip joint and dislocation of head of femur. Intracapsular air shows extent of joint space.

head laterally changes the relationship of the articular surfaces and the line of weight-bearing and eliminates contact between osteophytes at the joint margins. (4) Fusion, or the induction of ankylosis, consists of excision of the articular cartilage and transplantation of bone across the joint. Union is exceedingly difficult to obtain in the hip by such procedures, and in many cases free motion and a fair arthroplasty is the end result. Watson-Jones has therefore recently employed a five- to six-inch three-flanged nail (Smith-Petersen) for the purpose of complete internal fixation. This is an important factor in promoting osseous union, especially if the process of osteogenesis is defective.

The indications for these four types of operations differ. Since a majority of patients with osteoarthritis of the hip are beyond middle age, the lesion is frequently associated with a generalized osteoarthritis, particularly of the spine. In this event only operations which will

Fig. 14.—End result of arthroplasty following fracture of pelvis and head of femur.

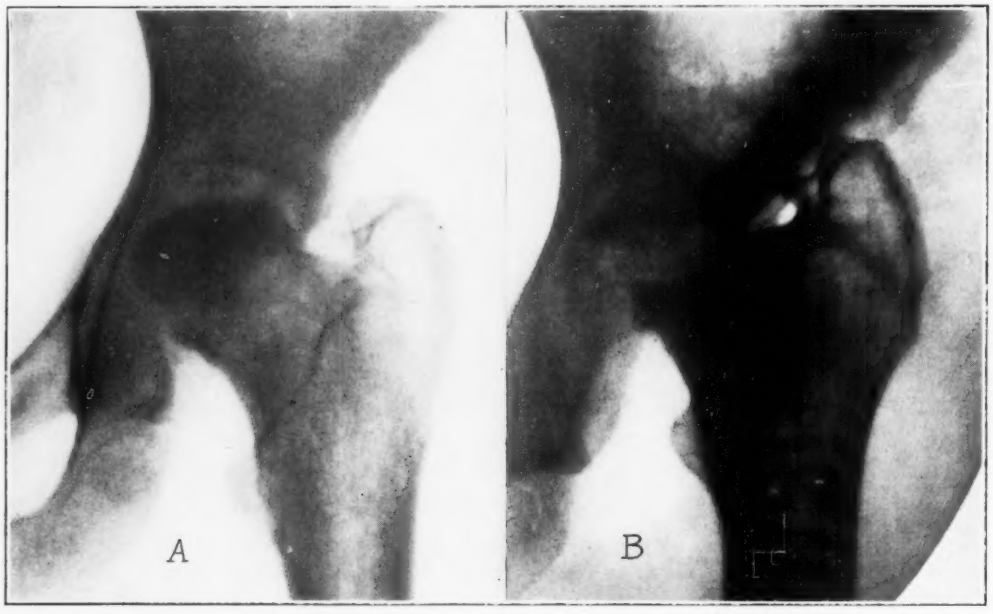

Fig. 15.—Arthroplasty following infectious arthritis; end result, showing aseptic necrosis and absorption of head of femur.

permit motion of the hip are indicated. If there are no symptoms referable to the spine and motion of the spine is free, fusion of the hip joint, when successful, is by far the most effectual means of relief.

In monarticular osteoarthritis the hip usually becomes a hinge joint fixed in external rotation, and the latter must be corrected if normal alignment is to be restored. This can often be accomplished by a reconstruction operation on the hip alone; otherwise, a supracondylar osteotomy just above the knee is advisable after the operative wound has healed, or, in young and robust individuals, at the time of the operation on the hip.

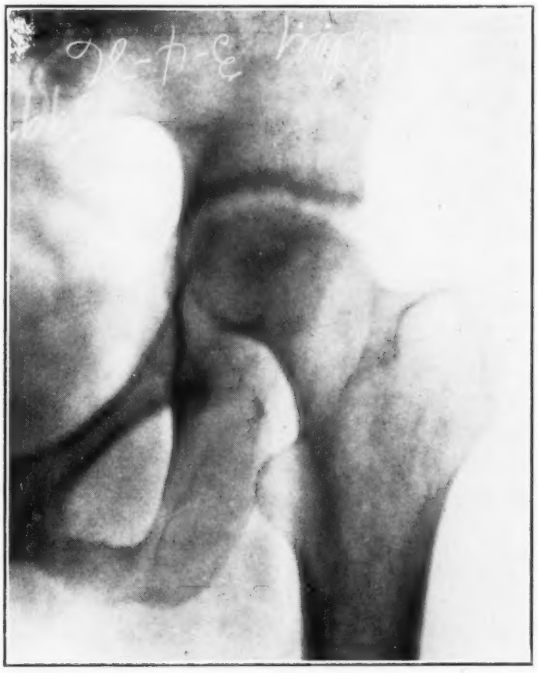

Fig. 16.—Reconstruction of a new joint by nature ("spontaneous arthroplasty") with about 50 per cent normal motion, after complete destruction of the joint by pyogenic infection.

The end results of arthroplasties of the hip in monarticular ankylosis as a result of pyogenic infection or trauma depend upon several factors: (1) A foundation of normal bone must be made for the articular surfaces. This may necessitate resection of a considerable portion of the head if subarticular cysts or dense sclerotic bone are present. (2) During the operation, care must be taken to preserve as much as possible of the capsular blood supply, since the ligamentum teres is severed during remodeling of the head. (3) Mechanically, there should be adequate superior support and free play of the femoral head within the acetabulum.

After arthroplasty, a new joint is formed by movement or friction between the osseous surfaces; this is the same process which is often

observed in the hip after a destructive lesion, and in ununited fractures of the long bones. Exploration after the elapse of one or more years will reveal a joint fluid and an investment of the joint with fibrocartilage, which extends into the subarticular spaces. The subarticular osseous structure is gradually consolidated by use and functional adaptation, providing support for the articular surface.

In conclusion, the fact is emphasized that every surgical procedure on the hip joint is an individual problem, to be undertaken with serious regard for both mechanical and physiopathologic principles. When these principles are faithfully observed, better results may be anticipated.

BRANCHIAL CYSTS

With Report of Two Cases of Cyst of the Cervical Sinus

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ON THE Surgical Service of the Research and Educational Hospital of the University of Illinois, College of Medicine from 1933 to 1938, 350 cases of cysts and tumors of the neck have been encountered. In this series the senior author has excised 26 branchial cysts arising from the second cleft and 5 cases of branchiogenic carcinoma. Prior to 1933 there had been 1 cyst arising from the third cleft (thymopharyngeal duct) operated upon and reported by Seed.[21] In this series of 350 cases there were 25 thyroglossal duct cysts, showing the ratio of lateral to median cysts. The 2 cases to be reported differed in anatomical position from that of the 26 cases of branchial cysts, although the histologic findings were the same. We believe these two cases represent a distinctive type of branchial cyst referable to the abnormal development of that portion of the embryonic branchial apparatus known as the precervical sinus.

The object of this study was to attempt to differentiate the true branchial cysts from branchial cysts which are known to us as persistent cervical sinus or cysts of the cervical sinus. These cysts are distinguished by their anatomical position. They lie in the lateral aspect of the neck just anteror and subjacent to the sternomastoid muscle. They extend down to the carotid sheath, but are entirely lateral to it. Sometimes they may send a short process up under the posterior belly of the digastric muscle.

Several important facts have been learned from this study. The outstanding are: (1) There is very little agreement among writers as to the origin of branchial cysts and fistulas. The theories presented will be summarized later. (2) There are several writers who mention the possibility of cysts arising from the cervical sinus per se; but (3) although the cervical sinus has been discussed in the formation of branchial cysts, to our knowledge no one has reported a cyst as a cyst of the cervical sinus.

The remainder of this paper will be divided as follows: (1) historical review, (2) embryology of the branchial region, (3) discussion of theories of formation, and (4) report of two cysts of the cervical sinus.

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I. HISTORICAL REVIEW

It is uniformly conceded that certain cysts and fistulas found in the lateral region of the neck are the result of persistence or anomalous development of the neck region of the growing embryo. These have been grouped together under the term branchial cysts and fistulas, even though there is good evidence to show that this terminology is incorrect.[16]

The first reported cases are attributed to Huncyowski in 1789, Dzonde in 1829, and Van Rathge in 1825.[2] It remained, however, for von Ascherson in 1832 in his report "De Fistulis Colli Congenita" to establish the branchiogenic origin of cervical fistulas. He distinguished clearly between lateral and median cervical fistulas and associated lateral cervical fistulas with incomplete closure of the branchial clefts. Following von Ascherson's work, discussion centered chiefly about the role the various clefts and the cervical sinus played in the formation of these anomalies. Von Heusinger, Bland-Sutton, von Cusset, His, and others believed that a fistulous opening might persist from any of the four clefts. Rabl thought that only the second cleft could be at fault. That the cervical sinus was responsible for the external aspect of the anomaly was maintained by von Ascherson, Kostaniecki, Milecki, and His. All of these authors ascribed to the branchiogenic theory, i.e., that the branchial clefts per se were at fault.[17]

A great revision of thought upon the subject was instigated by the work of Wenglowski in 1912. He first stressed the importance of the thymopharyngeal duct, derived from the third pharyngeal pouch, in the formation of anomalies. His work was based on five years' work studying seventy-five embryos and dissections of 144 infant cadavers.[6] Wenglowski's theories will be discussed later.

Since 1912, opinion has been divided on the subject. Some believe that Wenglowski's theories are most satisfactory; others believe that the branchiogenic theory still holds; no one has actually settled the question one way or the other.

II. EMBRYOLOGY OF THE BRANCHIAL REGION

The neck and pharynx of a human embryo of the third or fourth week are abnormally very unlike the analogous structures in the adult. On the lateral surface of the neck region of the fetus are several bar-like ridges called branchial arches. These arches run vertical to the long axis and are separated by intervening grooves. Five such arches develop. Each contains a cartilaginous core and an aortic vascular arch which connects the ventral with the dorsal aorta. (Fig. 1.) There also develop in each arch appropriate muscles and nerves. The first arch appears first and is largest. It is placed the farthest ventrally and at its dorsal ends an otocyst, the anlage of part of the external ear, appears.

The indentations which separate the branchial arches are called branchial grooves. These are ectodermal in origin and only four in number, as the fifth groove does not usually develop.

Subjacent to each branchial groove, the entoderm of the pharynx bulges outward between the arches to form complementary pharyngeal pouches. These pouches are entodermal in origin and five in number. They are separated from each other by the branchial arches which bulge inward into the pharynx. Between the pharyngeal pouches and the adjacent branchial grooves, there is only a thin membrane composed of ectoderm, entoderm, and intervening mesoderm. Ventrally the two series of pharyngeal pouches are separated by a longitudinal groove, the ventral pharyngeal groove.[7]

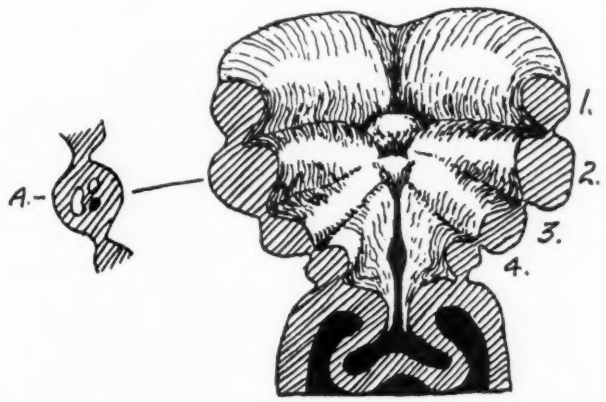


Fig. 1.—A diagram to illustrate the branchial arches and grooves. *A*, shows the cartilage, artery, and nerve contained in the arch. (After Hyndman and Light.)

As the branchial grooves and pharyngeal pouches enlarge, the wall of tissue separating them (separating membrane) becomes thinner, due to displacement of mesoderm. Eventually the ectoderm and entoderm of each groove and pouch unite; the thin plates thus formed sometimes rupture to make temporary openings between the primitive pharynx and the branchial clefts.[22] Soon the mesoderm again pushes in between the ectoderm and entoderm of the separating membranes, and the branchial arches enlarge and differentiate to form eventually many of the important structures of the neck region.

The first branchial arch on each side develops much more rapidly than the others. It soon bifurcates into a maxillary and a mandibular process. (Fig. 2.) The last arch, the fifth, grows very little. It lies caudal to the fourth cleft and is poorly defined along its posterior margin.

The growth of the first (mandibular) arch and the second (hyoid) arch takes place rapidly and in all directions. As a result of this rapid growth of the first and second arches and the lag in development of the third, fourth, and fifth arches, the slowly growing caudal arches appear to sink into a depression, the precervical sinus, as the

first and second arches "telescope" over them (Fig. 3). This sinus is responsible for many of the lateral cysts of the neck of epithelial character.

The sinus is widely open laterally for a time, but, as the hyoid (second) arch grows downward, the opening of the sinus to the exterior becomes narrowed to a small duct, the precervical duct (Fig. 3). Soon the posterior edge of the second arch fuses with the thoracic wall; all external communication of the sinus is obliterated and it becomes a closed space.

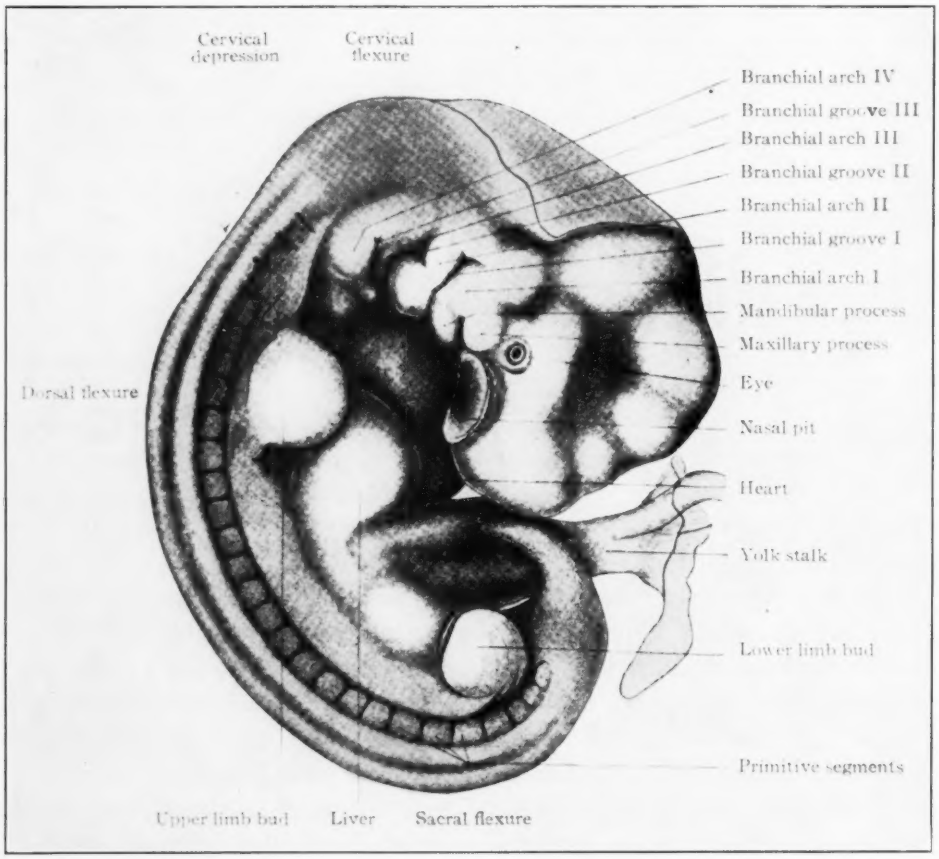


Fig. 2.—Human embryo of 7 mm., twenty-six days. Showing external aspect of the branchial apparatus. (After Bailey and Miller, after Mall.)

This closed space communicates with and encloses the second, third, and fourth branchial clefts and may communicate with the primitive pharynx if one of the membranes between the branchial groove and the pharyngeal pouch has ruptured. Both the sinus and the branchial clefts are lined with cells of an epithelial character. With further growth, the connections of the branchial clefts with the cervical sinus elongate into long branchial ducts. (Fig. 3.) Soon these ducts become obliterated, however. The ectodermal cells forming the walls disap-

pear and by the fifth to sixth week all trace of these structures is lost. Any failure of these retrogressive processes will leave cells of an epithelial character buried in the neck which may subsequently give rise to tumor, cyst, or fistula formation.

The maxillary process of the first arch eventually gives rise to the upper jaw, palate, parotid gland, skin of the upper lip and cheek, and enamel. The mandibular process of the first arch produces the lower jaw, teeth, sphenomandibular ligament, submaxillary and sublingual glands, malleus, incus, muscles of mastication, anterior belly of digastric, and skin of lower lip and jaw. The second arch gives rise to part of the auricle, epidermis of the neck (in part), the stapes, styloid process, stylohyoid ligament, lesser horns of hyoid, posterior belly of digastric, and other muscles. The third arch produces the body and greater horns of the hyoid bone and some pharyngeal muscles. The fourth arch differentiates to form part of the thyroid cartilage and some pharyngeal and laryngeal muscles. The fifth arch gives rise to part of the epidermis of the neck, thyroid cartilage, and laryngeal muscles.

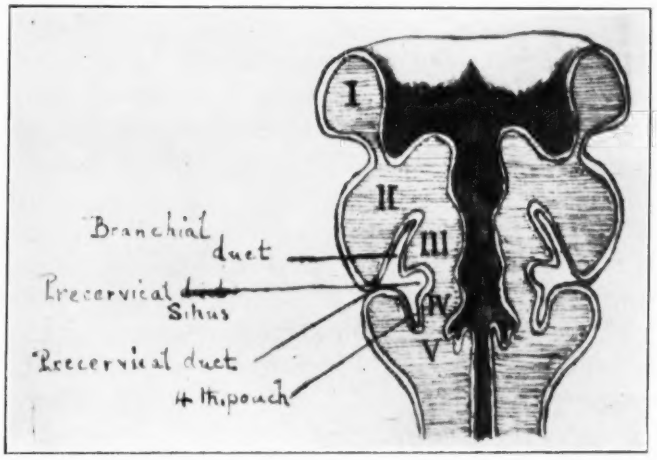


Fig. 3.—Showing the formation of the precervical sinus, the branchial ducts, and the precervical sulcus. (After McKenty, after Cunningham.)

All of the branchial grooves are normally obliterated, except the first, from which the external auditory meatus is formed.

The pharyngeal pouches play a greater role than the clefts. The first pouch eventually forms the tympanic cavity, the mastoid cells, and the auditory tube. The palatine tonsils are thought to rise from the second pouch. The third pharyngeal pouch is important, for from it arises a structure which many believe is the anlage of the majority of lateral cysts and fistulas of the neck. This structure is the thymopharyngeal duct from which the thymus gland develops. From the third pharyngeal pouches, bilateral ventral sacculations appear during the sixth week. These are the primordia of the thymic gland and are at first hollow, but soon they become solid epithelial strands. The

lower ends enlarge and unite to form the body of the gland. As the gland gradually sinks to assume its permanent position in the thorax, its connections with the pharynx become long and slender and form the thymopharyngeal ducts. From the persistence of portions of this duct, it is claimed that many branchial cysts and fistulas develop. The thymopharyngeal duct runs obliquely downward from the lateral pharyngeal wall to the sternum. It is closely associated with the cervical sinus and the lateral thyroid anlage.[8] Its importance in the formation of cysts and fistulas will be discussed more fully later. The inferior parathyroids also develop from the third pouch. The fourth pouch gives rise to the superior parathyroids. The fifth pouch is associated with the formation of the ultimobranchial bodies.[22]

III. DISCUSSION OF THEORIES AS TO ORIGIN OF BRANCHIAL CYSTS AND FISTULAS

All of the theories presented in the literature to explain the origin of branchial cysts and fistulas may be grouped under two large headings. These are: (1) the branchiogenic theory and (2) Wenglowski's theory.

The Branchiogenic Theory.—Many authorities believe that the branchial clefts per se are responsible for branchial cysts and fistulas. Some believe that the anomalies develop as the result of vestigial remains (epithelial rests) of the branchial apparatus[4, 6-8] which sooner or later grow and secrete to form cysts or fistulas. Others contend that incomplete closure of the branchial clefts is responsible.[11, 13] Rupture of the embryonic membranes separating the branchial clefts from the pharyngeal pouches is put forth as an additional factor by some, while others are of the opinion that anomalous development of the branchial apparatus is the cause. It would seem most logical, as has been stated, to assume that fistulas are due to complete or partial failure of a cleft to close; whereas, cysts arise from epithelial rests which develop to form their walls.[6]

A more important discussion among those who adhere to the branchiogenic theory, however, has centered about the question of what cleft, or what portion of the branchial apparatus, is most often involved in the formation of these developmental anomalies.

Certain authors attribute to the cervical sinus a major role in the formation of branchial cysts and fistulas. Frazer,[9] from his studies of the development of the lateral neck of embryos, came to the conclusion that the cervical sinus does not close as early and completely as is usually thought and might well be an important factor in the formation of anomalies.

Thompson[10] states that most cervical (lateral) cysts, including ranulas and submaxillary cysts, develop primarily from the cervical sinus, and

that their varying position is attributable to the shifting of muscles during the formation of the neck.

Rabl[30] in 1887 described the formation of the branchial clefts and cervical sinus and demonstrated how they were obliterated by the apposition of ectoderm with entoderm followed by disintegration of cells. He showed that the second cleft was much more apt to persist embryonically because of its greater depth and normally much longer persistence. He came to the conclusion that the second cleft and its attachments are almost invariably at fault in the formation of branchial anomalies. We are in accord with Rabl's views on this subject.

It is a well-established fact, as McKenty has stated, that: "If the development of vessels is normal, a fistula of the second cleft must lie between the external and internal carotid arteries; third cleft, common carotid and vagus; fourth cleft, bend around the subclavian on the right side and arch of the aorta on the left side." The great majority of these anomalies pass between the carotids and so, as Rabl originally contended, must be referable to the second cleft.

Dowd,[12] Whitacre,[18] McKenty,[7] and other writers contend that the formation of complete fistulas from either the third or the fourth cleft has never been found. Frazer[16] states that cervical cysts are referable to the second groove and its attachments as originally contended by Rabl.

The next question arises, however, as to what part of the primitive second branchial cleft is responsible in any given case of cyst or fistula.

Bailey[15] has shown that the relationship of branchial cysts to surrounding structures is constant and of four types.

The first type does not extend deeply. It lies at the anterior border of the sternomastoid, beneath the cervical fascia. (Fig. 4.)

The second type passes down to and lies on the great vessels. It is often adherent to the internal jugular.

The third type extends inward to the lateral wall of the pharynx, passing between the external and internal carotid arteries. In addition, a prolongation of the cyst passes upward as far as the lateral mass of the atlas and even to the base of the skull.

The fourth type is a mucus-containing cyst which lies entirely posterior to the common carotid, next to the pharynx. This type is never operated upon because it produces no signs or symptoms.

Rabl[30] theorized that the cervical sinus alone was responsible for branchial cysts. He stated: "If both internal and external openings of the second cleft close normally and the precervical sinus has not been obliterated completely, a branchial cyst will result which because of its epithelial structure may give rise to a branchial dermoid or carcinoma." (Fig. 3.) It is cases of this type, referable to enlargement of the cervical sinus, which we designate as cysts of the cervical sinus. However, in our experience they constitute no more than 4 or 5 per cent of all the branchial cysts.

Each of Bailey's four types is referable to anomalous development of a particular part of the embryonic second branchial arch. Only the second type is due to enlargement of the sinus per se. Frazer[16] has clearly elucidated this.

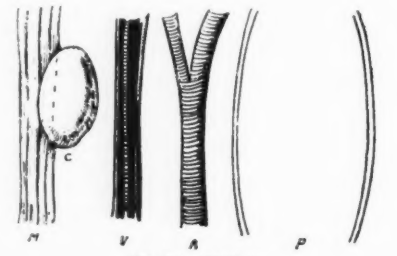


FIG. 484.—*TYPE I.*

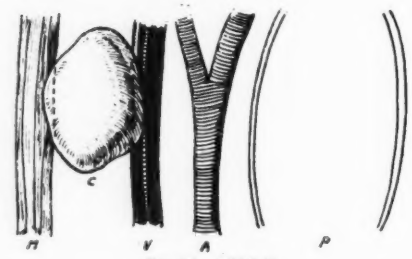


FIG. 485.—*TYPE II.*

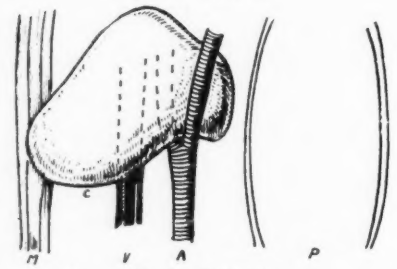


FIG. 486.—*TYPE III.*

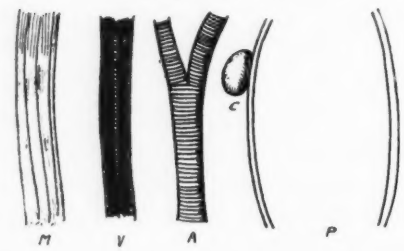


Fig. 4.—The four types of branchial cysts. *M*, Sternomastoid; *C*, cyst; *V*, jugular vein; *A*, carotids; *P*, pharynx. (After Bailey.)

Bailey's first type of branchial cyst is referable to the elongated tract leading to the sinus or to the second external duct leading into this tract (Fig. 5). The second type is due to enlargement of the sinus itself. Type 3 points to enlargement of the second external duct with more or less enlargement of the sinus also (Fig. 5). Type 4 is

of no clinical interest but is possibly due to enlargement of an internal duct.

Fistulas of branchiogenic origin are similar to the cysts in that they are likewise referable to the second branchial groove and may be divided into definite types.

The first type, incomplete external fistula, is one that has an external opening but no internal connection with the pharynx.

The second type, incomplete internal fistula, has an opening into the pharynx but none externally.

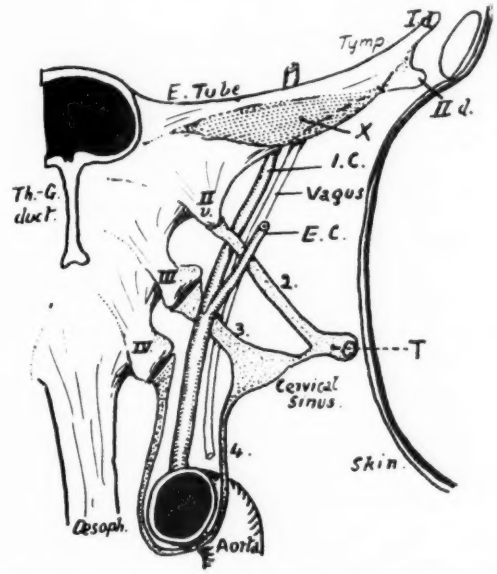


Fig. 5.—Schematic figure to show the vestigial structures in the neck, with their relations to main arteries and nerves. (The connection of the sinus with the surface is drawn out into a narrow tract [*T*]. The external duct running from the second pouch runs into this tract and not directly into the sinus.) *Id*, and *IId*, Dorsal angles of first and second lateral pouches; *IIv*, *III*, and *IV*, internal pharyngeal ducts derived from ventral angles of second, third and fourth lateral pouches; *2*, *3*, and *4*, external pharyngeal ducts derived from second, third, and fourth external grooves; *X*, layer of entodermal cells cut off from lower part of eustachian tube. (After Frazer.)

The third type, complete fistula, forms a complete tract with both internal and external openings. The anatomical relationships of these fistulas are identical with those of the corresponding cysts. They are really cysts which have an external or an internal opening or both. A particular part of the primitive second groove is responsible for each of these types. As Rabl demonstrated, an incomplete external fistula is a continuation of the ectoderm of the precervical sinus (elongated tract [T] leading to the sinus, Fig. 5). An incomplete internal fistula results when the sinus is obliterated, but the second furrow (external duct, Fig. 5) persists and communicates with the pharyngeal entoderm. A complete fistula occurs when the second cleft (external duct) fails to obliterate and breaks through into the pharynx and externally.[13] The site of the internal opening is at the tonsillar

region when due to the second cleft. If the third or fourth pouch were responsible, the internal openings would be at the pyriform fossa and the lower end of the pharynx.[16]

Thus, it is seen that, if we utilize Rabl's conception of the branchiogenic theory and add to it Frazer's and Bailey's contributions, it is possible to state for any given cyst or fistula what cleft or pouch is responsible and the particular portion of the indicated cleft from which the anomaly arose. This is very valuable clinically, and the truth of the concept is borne out by many researches, both clinical and experimental. There are, however, some who believe that the branchial clefts and cervical sinus have little or nothing to do with the formation of branchial cysts and fistulas. These ascribe to the theory of Wenglowski.

Wenglowski's Theory.—Wenglowski,[24] a Russian, in 1912, after detailed examination of the branchial apparatus in many embryos and after dissecting the neck region of many cadavers, propounded a new theory as to the origin of branchial cysts and fistulas. He presented evidence to show that the branchial apparatus could not leave remnants in the neck below the hyoid bone and came to the conclusion that all branchial fistulas or cysts are due to persistence of portions of the thymic duct.

There has been much discussion of this work since it was published. Some ascribe to Wenglowski's theory wholeheartedly, others are less enthusiastic, and still others have presented a great variety of good evidence to disprove the validity of the work.

The conclusions which Wenglowski came to are as follows:

1. There develops in man five to six branchial arches and as many clefts. These are not open.

2. The branchial apparatus lies from front to back, not from above downward. Its inferior border and the inferior border of that part which arises from it are made by the line which passes through the inferior border of the hyoid bone.

3. The branchial apparatus cannot leave remnants in the neck below the level of the hyoid bone.

4. The thymus originates from the third pouch in the form of a long canal running obliquely from the lateral pharyngeal wall to the sternum where the characteristic thymus substance begins to develop.

5. The thymic duct usually disappears partly or entirely. Occasionally the entire duct or one of its parts may persist.

6. The vestiges of the thymic duct change into a lateral cervical fistula or cyst. If the entire duct persists, a complete fistula will result; when only a part of it, an incomplete one.

7. The anatomical situation of the lateral fistulas corresponds very closely with the course of the thymic duct.

All of these conclusions have been repeatedly challenged by competent men. Of the foregoing statements, however, that which says

that the branchial apparatus cannot leave remnants in the neck below the level of the hyoid bone is most important. If this is so, only a small minority of branchial cysts and fistulas can be considered of branchial origin, for they frequently extend or open below the level of the hyoid bone. There is much authority, however, to disprove, or at least seriously question, Wenglowski's statement in this regard. For example, Kingsbury[14] states: "Vestiges are certainly not found only above the hyoid. The branchial apparatus certainly leaves remnants in the neck below the hyoid bone."

After a study of factors related to the formation of branchial cysts, Bailey[11] formed the following conclusions:

"1. As much as we admire Wenglowski's assiduous labor, his statement that the branchial apparatus never leaves remnants in the neck below the level of the hyoid, a statement which is the keynote of his hypothesis, must be incorrect. A persistent branchial cartilage is illustrated, a remnant, the origin of which cannot be disputed, situated in the lower third of a child's neck in the exact position where a branchial fistula commonly opens.

"2. A cervical auricle, by its structure clearly a homologue of the pinna, is situated at the point where a branchial fistula usually opens.

"3. Histologically a branchial fistula is usually lined by columnar epithelium, and its walls sometimes contain muscle. There is no reason why a thymic bud should contain these elements.

"4. The anatomical relationships of a branchial fistula as displayed during an operation for its extirpation are in keeping with those depicted in works on embryology as belonging to the cervical sinus and the second cleft which persists in the goat to open into the fossa of Rosenmuller."

There are many others who hold similar views so that, in spite of Wenglowski's researches, it seems to be generally agreed that the branchial apparatus can leave remnants in the neck below the level of the hyoid.

This indicates that it is possible for the branchial apparatus to be the causative factor in branchial cysts and fistulas whether they are situated above or below the hyoid. It does not disprove a causative role of the embryonic thymic duct in any given case, however. To determine the origin of any particular cyst or fistula, we must turn to a detailed anatomical examination with particular reference to relations, followed after removal by microscopic examination.

To differentiate cysts and fistulas of branchial origin from those of thymopharyngeal duct origin on the basis of anatomical relations alone is difficult, for the thymic duct is in close relationship with the sinus cervicalis and associated parts of the branchial apparatus. The following relations are of value, however.

1. A fistula of the second cleft must pass between the internal and external carotids. The great majority of complete fistulas lie in exactly this location.

2. A fistula of the thymopharyngeal duct must not pass between the bifurcation of the carotid. It lies anterior and very close to the carotid sheath, but does not pass between the arteries. Very few, if any, complete branchial fistulas do this.

3. The internal opening of a fistula originating from the second branchial cleft must be in the tonsillar fossa.

4. The internal opening of a fistula of the third cleft or pouch, from which the thymic duct originates, must be in the region of the pyriform fossa. The internal opening in clinical cases is almost always in the tonsillar fossa.

5. The location of the external opening is of no diagnostic value, for fistulas both of thymic origin and of branchial origin have openings at the anterior border of the sternomastoid which may range in vertical location from the external ear to the sternum.

Microscopically there are several findings of value in determining the anlage of a cyst or fistula.

1. It can be definitely stated that any cyst or fistula which contains in its walls typical thymic tissue with Hassall's corpuscles is of thymopharyngeal duct origin. These are very rare.

2. Any cyst or fistula wall which does not contain thymic tissue is probably of branchiogenic origin.

3. All contain lymphoid tissue, but this is not distinctive, for it is of an inflammatory or irritative origin and tells nothing of the source of the anomaly.

4. The great majority of cysts and fistulas are lined by squamous epithelium, although sometimes columnar or ciliated epithelium is found. There is no reason why a thymic bud should contain these elements. Much more than has been written here has been said for each side of the argument. The further pursuance of such a discussion, however, is a fit subject only for those who are skilled in the intricacies of the developmental anatomy of the neck region.

The simplicity and applicability clinically of the branchiogenic theory of Rabl have a strong appeal, and the preponderance of evidence in most cases tends to substantiate this theory.

There are, however, certain infrequent cases of branchial cyst or fistula whose anatomical position and microscopic appearance speak for an origin from the thymic duct. These should be so labeled.

The type of cases which we are presenting, cysts of the cervical sinus, are undoubtedly of branchiogenic origin as the name which we are giving them implies.

CASE REPORTS

CASE 1.—This patient, a male aged 48 years, was admitted April 1, 1938, with a history of a soft swelling of many years' duration in the left side of the neck

which slowly enlarged. The mass was painless. Physical examination revealed a soft swelling on the left side of the neck about the size of an orange, extending from the hyoid bone lateroposteriorly under the sternomastoid muscle and producing a swelling below the mastoid bone. About one-third of the tumor projected into the posterior triangle.

At operation (by R. B. M.) on April 2, 1938, incision was made from the mastoid process along the anterior margin of the sternomastoid muscle down to about the junction of the mid- and lower third. The deep fascia of the neck was opened and the mass found to be cystic. Prior to incision, aspiration had been done; a thick milky fluid which was seemingly purulent was obtained; on examination it contained cholesterin crystals but no leucocytes. This fluid was thicker than the consistency of that which is usually found in a branchial cyst. After cutting the sternomastoid, it was turned up giving an excellent exposure of the cyst, which was found to lie at the level of the hyoid bone. It passed only slightly anterior to the jugular vein but lateral to the carotid sheath extending out to the side of the neck. This confirmed the diagnosis of a cervical sinus cyst. The cystic mass was then removed without much difficulty, and the neck was closed, a drain being inserted into this space. Anatomically this cyst was located at the level of the hyoid bone, extending down into the posterior triangle.

Pathological Examination.—The cyst measured 5 by 3 by 1.5 cm. Its surface was irregular, rough and grayish red in color. On opening, its walls varied from 1 to 4 mm. in thickness; the lining was smooth, and grayish pink in color. The fluid had escaped. Microscopically, the cyst wall consisted of an outer layer of compressed connective tissue and fat infiltrated by and containing large deposits of lymphoid cells. The cyst was lined by squamous epithelium which was thrown up into low folds and papillary processes made further irregular by extensive thickening and keratinization of the squamous cells in their outer layers. There was no evidence of any thymic tissue. The diagnosis of cervical sinus was made upon anatomical position; histologically, it was typical branchial cyst.

Culture of the fluid removed from the cyst revealed no growth. Guinea pig inoculation for tuberculosis was negative.

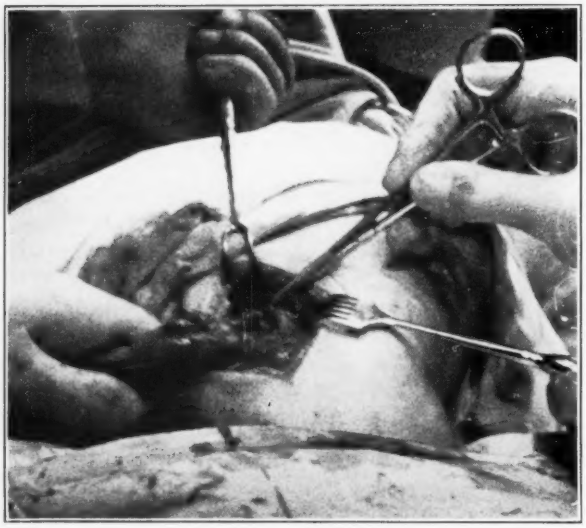
Case 2.—Patient, 20 years of age, white female, was admitted to the hospital April 22, 1938, complaining of a tense, tender swelling of one year's duration on the right side of the neck. Prior to three months before, when the patient's son was born, the mass had been about the size of an olive. However, during the past three months the mass had enlarged and become tender. On admission, the patient's temperature was 99.4° F.; the leucocyte count was 14,000. The mass, which was present under the sternomastoid muscle, distended the side of the neck on the anterior as well as posterior side of the muscle. The mass was situated laterally in the neck and did not present itself as is usually seen in a branchial cyst, in that it did not pass underneath the angle of the jaw; neither was fluctuation demonstrable by inserting the finger in the mouth as would be the case if the cyst were of the ordinary type. So the probable diagnosis was a cyst of the cervical sinus.

It is to be noted that a diagnosis of abscess of the neck was made in the dispensary and the mass aspirated, but the material contained cholesterol crystals and not pus.

At operation on April 23, 1938, incision was made from the mastoid process downward along the anterior margin of the sternomastoid. The platysma and deep fascia were opened and then the mass presented itself. A large syringeful of fluid was withdrawn from the cavity; this presented the usual features of a branchial cyst, i.e., cholesterin crystals. Then dissection was made down along

the anterior margin of the cyst, and it was freed inferiorly, then freed anteriorly. It was found to lie close to the jugular vein but did not present itself near the carotid artery, so the carotid sheath was not opened. The lateral side was dissected free and then the upper pole, which lay very deeply posteriorly, but did not extend under the posterior belly of the diagastric. It appeared obvious that we were dealing with a persistent cervical sinus cyst because of the anatomical posi-

A.



B.

Fig. 6.—*A*, At operation, showing cyst lying laterally. *B*, Resection of cyst which is lateral to the jugular vein, designated by the hemostat.

tion; the cyst being lateral to and slightly anterior to the jugular, entirely free from it and not extending up into the region of the bifurcation of the carotid, but lateral and inferior to the hyoid bone, although the upper process extended to the level of the posterior belly of the digastric. The cyst mass was excised without difficulty and the wound closed without damage.

Pathological Examination.—The cyst was oval shaped and measured 8 by 3.5 cm. The outer surface was glistening brown-red to yellow-pink. Approximately 3 ounces of thick yellowish fluid was still present in the cyst; microscopic examination of this fluid showed many cholesterin crystals. The wall varied from 3 to 7 mm. in thickness; it was alternately thickened and seminodular and of moderately firm consistency. The cyst was lined by a smooth, dull, or glistening epithelium. The thicker areas revealed considerable soft gray-yellow tissue upon cut section. Microscopically, the cyst wall consisted primarily of moderately hyperplastic lymphoid tissue with a supporting connective tissue stroma. It was lined by an epithelium which was alternately adult squamous and pseudostratified in character. The histologic picture resembled a branchial cyst, the anatomic relations proving it to be a cyst of the cervical sinus.

These two cases illustrate the embryologic anomaly known as cysts of the cervical sinus. Both specimens showed the histologic findings of a typical branchial cyst. They are distinctive because of their anatomical position.

SUMMARY

1. The historical background of branchial cysts and fistulas is reviewed.

2. A short sketch of the embryology of the branchial region is given.

3. Theories as to the origin of branchial anomalies are presented.

4. The theory of Rabl is ascribed to and an explanation is given whereby it is possible to determine the exact embryologic anlage of any given branchial cyst or fistula.

5. Detailed explanation of the origin of cysts of the cervical sinus is given.

6. Two cases of cysts of the cervical sinus are presented.

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RESULTS OF THE REPAIR OF VENTRAL HERNIAS WITH SUTURES OF FASCIA LATA

Review of Eighty-Five Hernias

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THE present use of fascia lata in plastic operations where the strength of the scar determines the result of the operation is based upon the work of Gallie and LeMesurier.[4, 5] Experimentally, they established several principles which govern plastic operations on aponeuroses, fasciae, and muscles. They found that when aponeuroses, fasciae, and muscles were sutured to each other, union by a rather delicate scar, which was formed from areolar tissue surrounding the structures united and which would not withstand tension, resulted.

When nonabsorbable suture material was used, the resulting scar, although stronger than that formed when absorbable suture material was used, was still not of satisfactory strength and the nonabsorbable sutures tended to cut through the structures they united. The overlapping type of operation was not attended by a stronger scar than other types of operations. Removal of the areolar tissue from the aponeuroses, fasciae, and muscles and preliminary scarification resulted in increased strength of the scars.

Gallie and LeMesurier[4, 5] also found that free or pedunculated transplants of fasciae lived unchanged when they had an adequate supply of lymph. These fascial transplants were found to conform to the precepts which Gallie and LeMesurier[4, 5] had established for the suturing of aponeuroses, fasciae, and muscles.

The recognition of a need for a more satisfactory suture material for use in certain plastic operations has been evidenced by the number of instruments devised for the obtaining of fascia lata for sutures. Obviously, one objection to the use of fascial sutures has been the necessity of making a long incision in the thigh to obtain the needed fascia lata. During the years 1929 to 1935, eight types of instruments for obtaining fascia lata sutures through one or two small incisions in the thigh were described in the United States and England. One of us (Masson[8]) designed his fascia stripper in 1933 and has used it without modification since that time.

TECHNIQUE

The method of repair of ventral hernias used for this series of patients has been described elsewhere by one of us (Masson[9]). The

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principles laid down by Gallie and LeMesurier are used. The aponeurotic surfaces are denuded of areolar tissue. No attempt is made to isolate the various layers of the abdominal wall. When possible, the entire thickness of the abdominal wall, except the skin and subcutaneous fat, is overlapped according to the method described by W. W. and W. J. Mayo. To save time and to make as accurate a closure of the peritoneal cavity as possible, a single strand of No. 1 chromic catgut is used to approximate the upper surface of the fascia from one side of the wound to the under or peritoneal surface of the other side, overlapping as much as possible without making undue tension.

Strips of fascia lata used as suture material are then used to further fix the upper layer to the under layer of the overlapped abdominal wall. It is advisable to carry some of the "living sutures" from strong normal tissue on one side across the weakened portion to the normal tissue on the opposite side. Sutures should also run at right angles to the transverse sutures.

The number of fascial sutures used in any given hernia depends first, on the length of the individual sutures and second, on the size of the hernia. As a rule, sutures from 8 to 12 inches (approximately 20 to 30 cm.) in length can be obtained from the thigh and, again as a rule, from 50 to 100 inches (approximately 127 to 254 cm.) of fascial suture material should be used for large hernias.

Several technical points which we have found valuable in the repair of hernias with fascial sutures might be stressed. An effort should be made to bury as much of the fascia as possible, thereby affording maximal contact between the fascial sutures and the aponeurotic and muscular portions of the abdominal wall. Whenever possible, the fascial sutures should be anchored by stitching through the fascia of a previous suture. Our tendency is to use more fascial material in the repair of a hernia than we did previously. We have had no experience with the many-tailed flaps of fascia lata which Gallie[3] recommends in preference to fascial sutures in the repair of large hernias.

Use of the Masson fascia stripper has proved to be an easy and successful means of obtaining fascia lata for sutures. Legs from which fasciae have been taken have caused no difficulty either immediately after operation or two to five years later. No hernias of muscle have been seen. As much fascia as is needed can be obtained; the fascia of both thighs can be made available with no inconvenience in draping the patient. Usually, enough fascial material can be obtained for the repair of a difficult hernia by introducing the fascia stripper once.

The majority of our patients who had recurrence of a hernia following the use of fascia lata as suture material were patients for whom a comparatively small amount of suture material was used. The fascial sutures were anchored often by suturing through previous sutures. When the size of the hernia rendered it impossible to overlap the ab-

dominal walls, either the edges of the defect were approximated by fascial sutures or the defect was "darned-in" as a seamstress darns a stocking. Silkworm sutures were used to prevent tension on the fascial repair during healing. The skin was closed with a continuous suture. Soft rubber drains were often used because of the large raw surface resulting from the repair of the hernia.

The patients being reported on herein were operated on by one of us (Masson) during the years 1933 to 1936, inclusive, and the hernias they had presented the most difficulty at operation of 299 ventral hernias repaired at the Mayo Clinic during the aforementioned period.

Table I contains miscellaneous information concerning the eighty-four patients. One patient had an incisional hernia at the lower sector of the midline and also another in the right side of the lower portion of the abdomen, which explains why eighty-five hernias afflicted only eighty-four patients. Four patients were more than 70 years of age. The average weight of 184 pounds (approximately 84 kg.) per patient indicates the type of patient that comprises this series of cases. Twenty-five of the eighty-four patients weighed more than 200 pounds (approximately 91 kg.).

TABLE I

MISCELLANEOUS DATA: 84 PATIENTS UNDERGOING REPAIR OF VENTRAL HERNIAS WITH FASCIA LATA

PATIENTS*	84
Hernias	85
Males	38
Females	46
Average age, years	50
Average weight, pounds	184
Hernias repaired previously	16
Average hospitalization, days	22

*One patient had two hernias.

Sixteen of the hernias had been repaired one to five times previously. A few of the hernias were as small as 2 inches (5 cm.) in diameter, but most were large. In the clinical records the hernias were often described as being "one-half the size of a watermelon," or "the size of a football or volley ball." Fig. 1 illustrates the type of hernia encountered in this series of cases. Fig. 2 illustrates the appearance of the abdominal wall one month after operation.

The site of the incisional hernias is shown in Table II. Because of the large size of the hernias and because many of them had been repaired previously, it was not possible to determine the type of incision through which the hernia had occurred.

Only one patient did not receive a spinal anesthetic. For thirty-seven patients it was necessary to supplement spinal anesthesia with inhalation or intravenous anesthesia because the location of the hernia

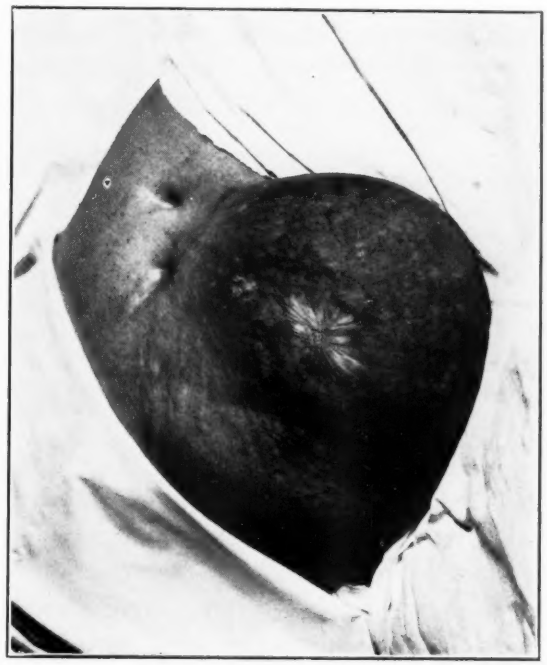

Fig. 1.—Huge recurrent postoperative ventral hernia.

Fig. 2.—Postoperative appearance of abdominal wall of same patient one month after operation.

TABLE II

SITE OF HERNIA: 85 VENTRAL HERNIAS REPAIRED WITH FASCIA LATA

SITE				TOTALS
UMBILICAL	EPIGASTRIC	INCISIONAL		
8	1	76		85
		Right, lower abdomen	38	
		Right, upper abdomen	13	
		Lower midline	20	
		Upper midline	4	
		Entire midline	1	
Totals 8	1		76	85

or the length of time necessary to repair it rendered a dose of spinal anesthetic that would be adequate, unsafe.

An average of 43 inches (approximately 110 cm.) of fascia lata sutures per hernia was used. The greatest length of fascia lata sutures used for any one hernia was 100 inches (approximately 254 cm.). All leg wounds healed by primary intention. No patient complained of discomfort in the leg postoperatively.

Postoperative complications are presented in Table III. Four of the five postoperative deaths were the result of pulmonary complications. The increased intra-abdominal pressure and the resulting decrease in vital capacity are important factors in the postoperative welfare of patients who have undergone repair of ventral hernias. Frequently it is necessary to place the patient in an oxygen tent immediately after operation.

TABLE III

POSTOPERATIVE COMPLICATIONS, FATAL AND NONFATAL: 13 OUT OF 84 PATIENTS UNDERGOING REPAIR OF VENTRAL HERNIAS WITH FASCIA LATA

COMPLICATIONS				TOTALS
FATAL		NONFATAL		
5		8		13
Pneumonia	3	Phlebitis	2	
Atelectasis	1	Parotitis	1	
Shock	1	Cystitis	1	
		Fecal fistula	1	
		Infected wound	1	
		Gout	1	
		Secondary skin closure	1	
Totals	5		8	13

In the one case in which death was assigned to shock, subtotal hysterectomy, bilateral salpingo-oophorectomy, and appendectomy were performed at the same time the hernia was repaired.

The phlebitis of one of the two patients who had postoperative saphenous phlebitis occurred in the same leg from which the fascia had been taken. There was no evidence that the removal of the fascia was referable to the phlebitis.

One patient whose transverse colon had been opened during the operation was afflicted by a fecal fistula which healed spontaneously. This patient's hernia was cured.

A soft rubber superficial drain was used in the treatment of fifty-one of the hernias.

Follow-up data were available for sixty-two patients, representing sixty-two hernias. The results are depicted in Table IV. Fourteen patients were examined personally for postoperative results and the information on the remainder was obtained by letter.

TABLE IV

END RESULTS: 62 TRACED PATIENTS OUT OF 84 PATIENTS UNDERGOING REPAIR OF VENTRAL HERNIAS WITH FASCIA LATA*

SITE OF HERNIA	RESULTS			
	PATIENTS TRACED	TREATMENT SUCCESSFUL, PATIENTS	RECURRENCE	
			PATIENTS	PER CENT
All hernias	62	57	5	8.1
Umbilical	6	6	0	0.0
Incisional	56	51	5	8.9
Right, lower abdomen	27	26	1	3.7
Lower midline	15	14	1	6.7
Right, upper abdomen	9	7	2	22.2
Upper midline	4	4	0	0.0
Entire midline	1	0	1	100.0
Hernias repaired previously	12	11	1	8.3

*Of 62 traced patients, 14 were examined postoperatively; information concerning the remainder was obtained by letter.

There was no complaint concerning the leg in any case. No hernias of muscle were noted. On examining the thighs of patients in this series, a distinct groove where the fascia had been removed could be palpated.

The following brief notes can be made regarding hernias which recurred after operation.

CASES OF RECURRENCE

CASE 1.—A woman who weighed 214 pounds (approximately 97 kg.) and who was 5 feet 1 inch tall. Her hernia extended from the ensiform cartilage to the pubis. It recurred only above the navel, where her wound was infected.

CASE 2.—A woman who weighed 235 pounds (approximately 106 kg.) and whose height was 5 feet 6 inches. Her hernia was situated in a low midline incision. It had been repaired twice previously. This patient's thighs were unusually short and the strips of fascia obtained from one of them were only 4 inches (approximately 10 cm.) long. Thirty-two inches (approximately 81 cm.) of fascial sutures were used in the repair of her hernia, as opposed to the average of 43 inches (approximately 110 cm.). In retrospect, it might have been well to have taken fascia from both of this patient's thighs, instead of from only one.

CASE 3.—A man who weighed 200 pounds (approximately 91 kg.). His hernia occurred in the right side of the lower portion of the abdomen and was described as being the "size of a football." Only 27 inches (approximately 69 cm.) of

fascial sutures, compared to the average of 43 inches (approximately 110 cm.), were used in the repair of this hernia.

CASE 4.—A man who weighed 180 pounds (82 kg.). He had a huge hernia in the right side of the upper portion of the abdomen. No cause for the recurrence of his hernia was found.

CASE 5.—A female weighing 179 pounds (81 kg.). Her hernia, which was the size of a "volley ball," was situated in the right side of the upper portion of the abdomen. One and one-half years after operation she was found to have a small recurrence. No cause was found for the recurrence.

COMMENT

Results of the repair of large or recurrent ventral hernias have always included many failures. In 1923 one of us (Masson[7]) reported results of the repair of 596 ventral hernias, 84 of which had been repaired previously. In 22.48 per cent of the cases weak wounds were present. Only 3.35 per cent of the patients, however, reported that they were not improved by the results of their operations.

Branch in 1934 reported the results of repair of 240 incisional hernias. The repair was accomplished by overlapping the abdominal walls and suturing with silk or catgut for all but 14 patients in whom the defect was so large that it could be repaired only by weaving fascial material over it as recommended by Gallie. Recurrence of the hernias was reported in 19.6 per cent of the cases. For 14 more difficult hernias which were repaired by weaving fascia lata over the defect, the recurrence rate was 21.42 per cent.

Grace and Johnson in 1937 reported on the results of the repair of 22 lateral ventral, 16 umbilical, and 8 epigastric hernias of patients, all of whom were more than 50 years of age. The recurrence rate was 36 per cent for the lateral ventral, 31 per cent for the umbilical, and 62.5 per cent for the epigastric hernias. The hernias were repaired with catgut, fascia, or silk.

Burdick, Gillespie, and Higinbotham in 1937 reported on the results of the use of fascial sutures in the repair of 1,485 hernias. Autogenous, homologous, and ox fasciae were used. In 7.9 per cent of hernias repaired with autogenous fascia, infected wounds occurred. The combined recurrence rate for 98 combined umbilical, epigastric, and ventral hernias was 44.89 per cent. These authors no longer regard fascia as the material of choice for use in the repair of the more difficult hernias, except in the repair of some unusually large ventral hernias, where they use the pedicle graft of fascia lata as recommended by Wangensteen.

SUMMARY AND CONCLUSIONS

The results obtained in the repair of 85 ventral hernias with sutures of fascia lata are reported. The hernias were large. The patients were obese and of middle age. Of the 62 patients who were followed

two to five years, there was recurrence of the hernia for 8.06 per cent. Of 12 ventral hernias which had been repaired one to five times previously, only 1, or 8.33 per cent, recurred; 1.17 per cent of the wounds became infected. The mortality rate for the series was 5.95 per cent. Pulmonary complications constituted the most common cause of death.

We conclude that ventral hernias which we have not been able to repair previously can be repaired with sutures made of fascia lata.

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DISPOSITION OF THE SAC IN OPERATIONS FOR OBLIQUE INGUINAL AND FEMORAL HERNIAS

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NEARLY fifty years ago it was suggested that an adequate operation for the repair of oblique inguinal and femoral hernias required primarily a complete obliteration of the sac. The canal was considered secondary and practically of no importance in the treatment of femoral hernia. Relative to these views, a number of procedures were described which aimed at elevating, invaginating, and fixing the sac above the level of the internal ring. In the succeeding years, however, with attention concentrated on improving the methods for repair of the canal, the earlier suggestions regarding the sac were either overlooked, forgotten, or perhaps considered unnecessary. Extraperitoneal transfixion has survived and is employed by some. Others, conscious of the necessity of more adequate obliteration of the sac, have resorted to the intra-abdominal approach. It is not the intent of this report to decry these operations nor the well-known methods of dealing with the canal. I am of the opinion though that too much reliance is placed on the plastic repair of the canal and that not sufficient attention is generally paid to the disposition of the sac.

Any operation which leaves any portion of the sac engaged in the ring, whether or not fixed by suture, is faulty. When approached through the canal, it is, from an anatomical and a mechanical standpoint, technically almost impossible to simply ligate the sac above the internal ring. The so-called high ligation of the sac as generally practiced must therefore be considered inadequate. That a nipple of bulging peritoneum so often remains in the ring after such ligation can readily be determined by the examining finger, if the patient, operated upon under local anesthesia, is requested to strain or cough. It is possible that such a situation might be a factor in the problem of recurrences. A simple and efficient method which I have employed for overcoming this condition prompts this report.

CASE REPORT

In 1934, J. T., a male, aged 60 years, presented himself with a reducible left femoral hernia of many years' duration (Figs. 1 and 2). Noteworthy of other physical findings were a blood pressure of 220/90, chronic bronchitis, emphysema, and a degree of myocardial damage. A truss could not be worn. It was at once apparent that, since the protrusion had evidently dissected Poupart's ligament

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free along its entire length, the repair of the supporting structures might not be satisfactory. Based upon the opinion of earlier writers that repair of the femoral canal was unnecessary, if a proper high fixation of the sac were performed, the following operation was carefully planned and executed.

Under local anesthesia and through an inguinal incision over Poupart's ligament, the sac, after being emptied of its contents, was dissected free from the surrounding tissues, including the sheaths of the femoral vessels. The sac, when thus cleared, measured twelve inches in length. Its neck admitted four

Fig. 1.

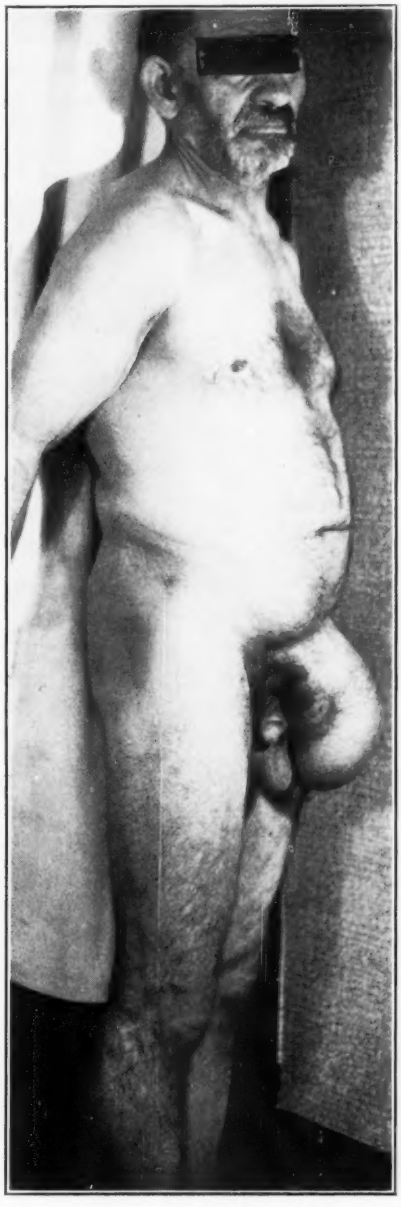

Fig. 2.

fingers. No adhesions were present. A very small left-sided McBurney muscle-splitting incision was made and through this the index finger was directed within the peritoneal cavity and hugging the anterior abdominal wall toward the femoral canal. The distal end of the sac was grasped by a long forceps invaginated into itself and guided by the aforementioned finger through the McBurney incision. Traction of the sac as it protruded through the abdominal wall thus produced an inverted peritoneal cone with its apex at the abdominal incision and its base above Poupart's ligament. The protruding sac was fixed to the abdominal wall by incorporation with the sutures used to close the incision. One suture was placed at the site of what was originally the femoral canal. No other attempt at repair of this region was made. Recovery was rapid, the patient being discharged on the tenth postoperative day. Examination of the patient four years later revealed an excellent result, there being no evidence of recurrence whatever. As a matter of fact, the region of the femoral canal appears retracted (Fig. 3).

Fig. 3.—Photograph taken August, 1939, showing retraction of the femoral region. The patient is retracting the redundant skin, a fold of which is visible.

As may be surmised, and as a search of the literature reveals, a femoral hernia of such size is extremely rare and consequently its successful repair by such a simple procedure even more so. However, the result encouraged its adoption in all indirect inguinal hernias, particularly the very large ones. Though the number of operations have been regretfully too small for a statistical review, the gratifying obliteration of the sac justifies a description of the procedure which may prove useful to others in a great many cases. No opportunity has as

yet presented itself, but the possibility of dealing with sliding hernia by this method is strongly considered, and at least appears theoretically logical.

PROCEDURE FOR OBLIQUE INGUINAL HERNIA

Practically all hernias are repaired under local anesthesia. The inguinal canal is exposed in the usual manner. Since undue strain on the resutured structures is surgically unsound, the external oblique fascia is incised closer to Poupart's ligament. After the sac has been

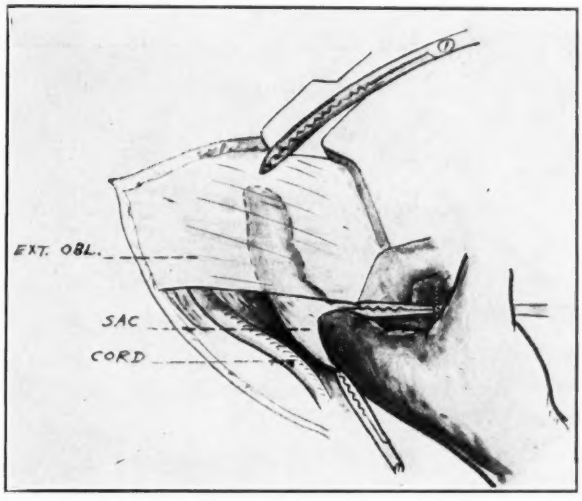

Fig. 4.

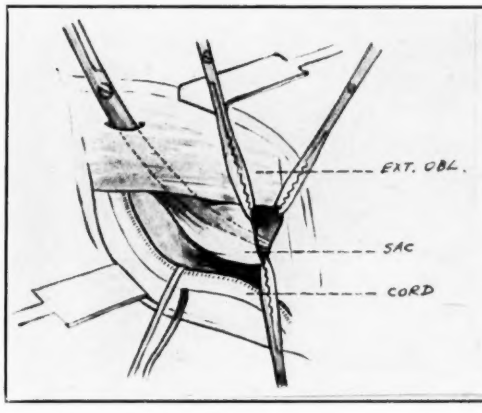

Fig. 5.

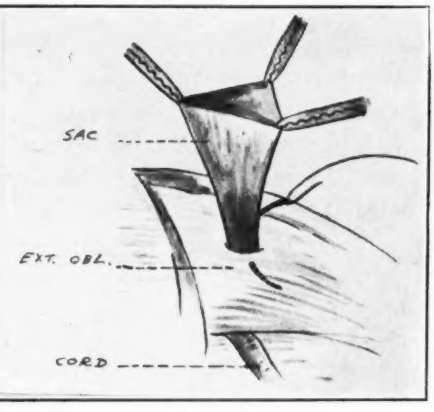

Fig. 6.

well separated from its bed, opened and freed of any adherent abdominal contents, the index finger is inserted through it into the abdominal cavity above the internal ring (Fig. 4). This finger serves as a guide for directing a curved forceps which pierces the abdominal wall and hugging the peritoneal surface of the wall is guided into the sac (Fig. 5). The end of the sac is then grasped in the forceps and, still hugging

the anterior abdominal wall, is withdrawn as far as possible without undue tension. The invaginated protruding neck of the sac is sutured to the external oblique fascia and the excess sac removed (Fig. 6). The examining finger at the internal ring can now detect a hollow peritoneum-covered cone, its base toward and above the ring and its apex at the abdominal wall puncture. If the patient is requested to cough or strain, no peritoneal nipple can be detected The canal may now be repaired as the surgeon desires. A spica bandage of soft stockinette renders pressure and support. Elderly individuals are allowed out of bed on the first postoperative day; others by the third day, or as soon after as possible.

CONCLUSIONS

1. An unusually large femoral hernia has been successfully repaired by a very simple method.

2. Any operative method for the repair of oblique inguinal and femoral hernia, particularly large ones, must include in its execution a complete obliteration of the sac above the internal ring.

3. A simple, adequate, and efficient method for accomplishing this end is described.

THE CAUSE AND CURE OF INGUINAL HERNIA

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ANATOMY

THE abdominal cavity is about 30 cm. in height in the upright position. It is filled with organs, semifluid in their consistency, whose weight exposes the lower part of the abdominal wall to a considerable pressure. There is a small positive pressure even in the upper abdomen. The walls of the abdomen are muscular structures and we have been accustomed to assume that these muscles carry the intraabdominal pressure. In this assumption we are probably mistaken, for muscles have a function of their own; i.e., the performance of mechanical work by actively contracting. Moreover, when a hernial extension of the abdominal cavity develops, it has no difficulty in pushing these muscles out of its way, however strong and well placed they may be. The essential factor in carrying the intra-abdominal pressure seems to be the thin, but very strong, fascial sheet which invests the abdominal cavity like a sac. In different localities it has been given different names. In the region where inguinal hernias are found, it is called the transversalis fascia.

PHYSIOLOGY

Fascia is formed of collagen fibrils, whose only function, so far as we know, is the carrying of constant tension in an elastic way. The strength of fascia is remarkable.* In a dog, when air is injected into the abdominal cavity, the pressure can be raised to several pounds per square inch before it ruptures the thin fascial sheet investing the parietal peritoneum. This investing sac gives way first in the region of the esophagus and, if the pressure is forced to a higher figure, it ruptures in front in an irregular longitudinal rent, a little lateral to the midline. The fascia stretches considerably before rupture takes place, which is not surprising, for fascia is very distinctly an elastic tissue and any fascia or tendon when cut draws away in both directions to a surprising distance.

PATHOLOGY

The fibrous sac investing the abdominal cavity may be torn by wounds, and it may be incised intentionally, as in an abdominal operation. If part or all of such a wound remains unrepaired, some of the abdominal contents are pushed out into the surrounding tissues and we have the simplest type of hernia. Incisional hernias following operation are common examples.

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*Unpublished work done in the laboratory of Dr. J. E. Sweet, New York, N. Y.

Very rarely we see inguinal hernias which appear to have been caused by such a rupture of fascial investment of the abdominal cavity. In thirty years I have seen one. Much more important is the fact that this fascial investment of the peritoneal cavity has certain weak areas which sometimes prove incapable of supporting the intra-abdominal pressure and gradually give way. In Arabia, as elsewhere, the internal abdominal ring is by far the most common site of such a failure, and Hesselbach's triangle is next. The umbilicus is a less frequent site of a hernia, but failure there is common enough. We have seen one femoral and one obturator hernia.

These hernias increase in size gradually and push normal muscles out of their way with no difficulty. Obviously in such a case the intra-abdominal pressure has risen above the resisting capacity of the abdominal wall. This may be due to an increase of the pressure within the abdominal cavity. Unquestionably that is the case in patients with ascites, where the cavity as a whole may be stretched to double its normal size, with a hernia in each inguinal region and a third at the umbilicus. There are certain cases of obesity, too, where a great increase in the intra-abdominal pressure must be the cause of the patient's hernia.

Hard work is associated with a temporary and fluctuating increase in the intra-abdominal pressure. Popular opinion ascribes many hernias to this cause, particularly if such hard work is continued over a long period. We have seen no hernias in Arabia which seemed due to such a cause. Hard work, indeed, causes hypertrophy of muscles and of fascia and tendons as well, and granted normal health it is very doubtful if any amount of work will lead to the appearance of a hernia.[1, 2] Some carefully observed series of cases have been reported in which small hernias were cured by exercise and the increased muscular and fascial development that followed.

Experience in Arabia has led us to believe that a hernia is usually caused not by a rise in the intra-abdominal pressure, but by a diminution in the strength of the fascial structures of the abdominal wall. In many cases advancing age is the cause. As time passes, the skeletal structures weaken and the thin old men of Arabia show various bulges in their abdominal walls, notably a slender triangle above each external ring. The fascial layer which invests the peritoneal cavity is not exempt from this change. About 25 per cent of the hernias which we see are first noticed at fifty years of age or older. The average age of our patients is 43 years. There are, of course, many hernias in younger people, but with them, too, there seems no reason for supposing that the intra-abdominal pressure is high. The patients are not of laborious habits nor is there any abdominal distention. Evidently some cause operates to reduce the pressure-resisting capacity of the abdominal wall.

Eventually its strength sinks below the critical level and at its weakest point it begins to yield. That is to say, at that point a hernia develops.

When this happens, the pathologic change is confined to a small, sharply limited area. This can be seen, even in the very early cases. Twice we have operated upon direct hernias which were only a few days old. Pain was the only symptom. The swelling was too small to be detected externally. An area the size of a dime was found giving way. In older and larger hernias the opening had been stretched to larger dimensions, but the pathologic change was limited to this locality. Tissues seemed normal elsewhere.

The area of pathologic change is small, and no change is seen in the transversalis fascia elsewhere. Nevertheless, it is evident that in the affected area the pathologic change is very marked. The intraabdominal pressure now distends this area almost without hindrance and the developing hernia penetrates between the muscles and descends into the scrotum to be bellied out there, by the pressure within, into a narrow necked extension of the peritoneal cavity which may attain the size of a coconut.

There would appear to be only one plausible explanation for this remarkable phenomenon. While the fascial investment of the parietal peritoneum remains normal, all points carry the intra-abdominal pressure on the elastic recoil of the collagen fibrils, and so long as the load can be carried in that way there is no trouble. But, as the fascia weakens, the load eventually becomes too heavy for the elasticity of the fibrils and they rupture. Evidently if this injury includes a considerable percentage of the fibrils, the mischief is done, for the abnormal stretching which immediately follows ruptures many more and the pressure-resisting capacity of this small area drops far down, probably almost to zero.

EVOLUTION AND LATER HISTORY OF A HERNIA

It is interesting to observe with some care the later history of such a hernia. It pushes to one side the muscles that are in its way, displacing them considerably when it becomes large. It grows larger and larger for a period which in Arabia averages about two years. The increase in size then stops, and the hernia remains stationary in size throughout the rest of the man's life. This spontaneous arrest in the growth of a hernia is important. Apparently it always takes place if the hernia is allowed to complete its development. I have seen a number of patients whose hernias had a second period of growth after years of quiescence.

This arrest in the growth of a hernia must be caused by a compensatory hypertrophy of its fascial investment. There are no muscular elements which can help in any significant way. In this connection it is interesting to note that the hernias seen in cases of severe ascites are

comparatively small. The intra-abdominal pressure is very high in these cases and is in no way relieved by the development of the hernias. Nevertheless, their increase in size is soon arrested, doubtless by a compensatory hypertrophy of their fibrous investment, and they remain small.

TREATMENT OF HERNIA, HISTORICAL

The hernia problem as outlined above has been before the surgeon for centuries. Incantations and cautery irons and trusses, all have been used in its treatment. The modern treatment of hernia dates from Bassini.[3] His article published in 1890 is one of the milestones of surgery. Bassini did two things. He removed the sac, ligating the neck high up, thereby re-establishing a normal peritoneal cavity. He sutured the conjoined tendon to Poupart's ligament, thus reducing materially the empty intermuscular gap over which the transversalis fascia must support the intra-abdominal pressure. Since the appearance of that article, Bassini's ideas have ruled supreme. In the disposition and arrangement of the available muscular and fascial structures endless minor variations have been suggested, but none have proved significant, either in principle or in results.

Following this operation, 90 per cent of our hernia patients remain permanently cured. The results could be much worse, and, compared with conditions before Bassini's day, it represents a very great advance. No one is satisfied with it now and there have been many efforts to devise a better operation. In such an attempt the first question is not why we fail in 10 per cent of our cases, but why we succeed in 90 per cent of them.

We succeed in 90 per cent of our cases probably because in most of them the increase in the hernia's size has been arrested long since. The fascial investment of the peritoneum, or rather that extension of it which surrounds the hernial sac, has undergone compensatory hypertrophy and now carries the intra-abdominal pressure without embarrassment. Any aseptic ligation of the neck of the sac will cure such a hernia. Doubtless this is why Kocher,[4] after simple high ligation of the sac, was able to report results quite equal to Bassini's although he undertook no treatment whatever of the abdominal wall. Russell,[5] of Melbourne, has written extensively to show the same thing. In compensated cases which are stationary in size, removal of the sac is all that is needed, as Russell has said so many times. As a matter of fact, the essential feature is the ligation of the neck and restoration of the peritoneal cavity. The sac itself may be better left behind. In large hernias a tedious and difficult dissection is avoided by doing so.

Nevertheless surgical opinion is unanimous in asserting that recurrences are less frequent following Bassini's operation. In a large hernia the gap between the conjoined tendon and Poupart's ligament may be

an inch across. A well-executed Bassini repair will reduce it to one-third of that diameter. Nothing is more certain than the fact that a hernia can recur through a hole much smaller than that. It is evident from the most casual observation of recurrent hernias that, once a hernia is started, no possible arrangement of the muscles offers it an effective barrier. A hernia goes straight through a normal abdominal wall and similarly it goes through any abnormal wall which we may create. Our only hope is to prevent getting it started. The reason why a well-executed Bassini repair helps at least a little in preventing recurrences is that it affords support to the transversalis fascia so that the initial overstrain is prevented, and the hernia does not develop. In large hernias this added security resulting from the Bassini procedure is important.

We come to the second question. Why do we fail in 10 per cent of our cases? Sometimes we fail because compensation has been established with little or no margin, and, when we replace in the abdominal cavity the contents of a large hernial sac, the intra-abdominal pressure is sufficiently raised to bring it again above the resistance level of the transversalis fascia and a hernia begins to re-form. This may make itself manifest by the development of a hernia on the opposite side.

It is possible also to cause recurrences by overconscientious dissection and too high a ligation of the neck of the sac. We have all noted the thinness of the fascial sheet investing the abdominal cavity when the neck of the sac is left behind, and our dissection follows the fascia into the pelvis. Some years ago, feeling the urge for a very radical attack on this matter of recurrences, we started sacrificing the deep epigastric vessels as a routine. After a dissection which carried us well into the pelvis, we pulled into view the most distant fascia that could be dragged forward and ligated the neck of the sac, as we still called it, at that point. This was followed by a high percentage of recurrences. We had pulled out into view fascia normally lying on the floor of the pelvis and had left that weak and inadequate structure to carry the intra-abdominal pressure. The surprising thing was that in about 75 per cent of the cases it succeeded in doing so.

For the sake of brevity, we have considered direct and indirect hernias together. Bassini's operation, however, has been found very unsatisfactory for direct hernias. Apparently the transversalis fascia is weaker in the direct hernias than in the indirect and its adequate repair is much more uncertain. We have found no way to secure good results in direct hernias, except by transplanting a free patch of fascia lata and suturing it in place over the weak area.

EXPERIMENTAL WORK

There has been little experimental study of this subject. Our own experiments have been confined to incisional hernia, which we regard

as the simplest type. When the fibrous sac which surrounds the peritoneal cavity is incised and left unsutured, a hernia follows. The intra-abdominal pressure forces the intestines and omentum out into the surrounding tissues. This cavity is soon lined with peritoneal cells and thus comes to constitute an abnormal extension of the peritoneal cavity. Such a hernia can be readily produced in a dog by removing all muscular and fascial structures and by allowing the intestines to hang down into the subcutaneous tissues.* In each of ten dogs a large patch of the abdominal wall was removed in this way. The intestines hung down in a sessile sac, which attained a depth of four inches.

All of these dogs recovered spontaneously. In from two weeks to twenty days the contour of the abdomen became entirely normal. The new cavity was lined with peritoneal cells and between this layer and the skin a fibrous sheet was laid down. Evidently this sheet contracted until the intestines were lifted back into place. Laid down at first in an irregular way, at the end of the process it was a close grained and firm sheet of fascia, carrying the intra-abdominal pressure efficiently.

So far as we know, two things happen in such a case. Collagen fibrils are laid down. Later they contract. Certainly the human organism can lay down scar tissue with its collagen fibrils. Moreover, these can contract, as anyone who cares for cases of burns most vividly realizes. Why then does not the human incisional hernia spontaneously recover? Perhaps because the dog reacts to a slighter stimulus and thus keeps up for a longer time this laying down of scar tissue, which will later contract and cure the hernia.

We hoped to find some agent which would stimulate artificially this laying down of fibrous tissue over a period sufficiently long to bring about the cure of the hernia. With this in mind, an emulsion of paraffin particles was injected around a growing incisional hernia in the lower abdomen of a difficult case of prostatic hypertrophy. Constant coughing was enlarging the hernia. The reaction following the injections stopped further increase in size and even caused the hernia to shrink appreciably, but further than this we could not carry the patient.

At present many hernias are being cured by the injection of irritating fluids around the internal ring. This is really a Bassini operation. The fibrous proliferation which follows such injections narrows the open space between the abdominal muscles, which is much the same result mechanically as is secured by suturing the conjoined tendon to Poupart's ligament. Second, by means of an acute inflammation of the peritoneal surfaces of the neck of the sac, there is accomplished a permanent adhesion of these surfaces, which amounts to an aseptic ligation of the sac. Success depends on a fairly active inflammation of the peritoneal surfaces, but, once accomplished, there is no reason why this

*Unpublished work done in the laboratory of Dr. M. C. Winternitz, New Haven, Conn.

procedure should not be followed by about the same percentage of successes as the Bassini operation. How serious the inherent risks may be experience will have to show us.

OPERATIVE TREATMENT

We owe to Nageotte and Sencert[6] and to numerous investigators since a new conception of the character of fibrous tissue. Working with tendons and fascia, they found that, after preservation in 70 per cent alcohol, ox fascia upon introduction into the human body is not absorbed but remains permanently in place, unmodified in thickness or size and presumably unchanged in strength. The physiologic implications of this are very great. It is perhaps the most important contribution to the physiology of fibrous tissue that has been made for some time. According to this conception, the feltwork of collagen fibrils which constitutes a fascial sheet is a more or less nonliving framework in the interstices of which rest living cells. Preserved as indicated, such a framework from an ox can be accepted and permanently utilized as a tenement for human cells. Our realization that this opens a new era in the treatment of hernias, we owe largely to Koontz,[6] of Baltimore.

But this discovery eventually will contribute vastly more to the treatment of hernias than a new and nonabsorbable type of catgut. Ox fascia is easily available in sheets of any thickness and any size. Granted their permanence, and the evidence for this seems entirely convincing, we would seem to have here a means for making recurrences quite impossible. It is not difficult to introduce a patch of ox fascia behind the muscular structures of the abdominal wall, between them and the peritoneum. This reinforces the fascial investment of the abdominal cavity so that in this particular area a hernia is quite out of the question.

The operation is simple. A high hernia incision, followed by splitting the external oblique fascia, exposes the internal oblique muscle which we split one-half inch from its lower edge, thus entering the peritoneal cavity just above the internal ring. LaRoque[7] introduced this incision, at least to our attention. It affords an excellent exposure for the dissection that follows. The sac is amputated and left in place. The deep epigastric vessels are ligated and cut; the vas is carefully preserved and brought around one of the edges of the patch when that is introduced. The dissection is carried in each direction far enough to accommodate a fascial patch one and one-half inches in each dimension. This is left in place without suturing. The intention is that it rest in place without-out wrinkling, but in some cases we have wrinkled it a good deal. It extends downward a little below the edge of Poupart's ligament. The internal ring and Hesselbach's triangle are both covered. The opening into the peritoneal cavity is closed whenever convenient; the internal oblique muscle is closed over the patch. The external oblique fascia is repaired, and the skin sutured.

We have operated upon 62 hernias in this way, and the results have been extremely satisfactory. So far as we know there have been no recurrences and not the slightest inconvenience nor discomfort because of the patches. Of the 62, 46 were indirect hernias, 14 direct, and 2 epigastric hernias. For our occasional sliding hernias we are developing a different and more extensive procedure.

There is, however, a simpler way of meeting the indications. The reinforcing patch can be placed within the peritoneal cavity instead of outside. A LaRoque incision, as detailed above, gives access to the peritoneal cavity. The neck of the sac is cauterized on its inner surface and the mouth of the sac closed by two or three fine silk sutures. A fascial patch not over one inch or one and one-fourth inches is covered on one side with a free graft from the omentum and fastened in place over the mouth of the sac, with its omental surface next the intestines. One of the sutures which closes the mouth of the sac includes in its bite the midpoint of the patch and in addition four light sutures at the corners stretch it out accurately in position. The abdomen is closed in the usual manner.

In this operation the dense adhesions which follow the use of the cautery are utilized to afford a firm and permanent closure of the neck of the sac. In Arabia the cautery is regarded as a panacea, and every surgeon has many opportunities to observe its astonishing capacity to stir up a fibrous tissue reaction. We feel quite sure that this fibrous tissue reaction not only will close the neck of the sac, but also will bring about a firm incorporation of the patch into the adjacent tissues.

This operation seems to offer an efficient repair of damaged structures, with a minimum of operative injury elsewhere. Its ease and simplicity are very alluring, it being less work, if that is possible, than an interval appendix. Our experience at the moment covers 22 cases and is entirely favorable, for the treatment of simple hernia both direct and indirect; we regard it as the operation of the future.

OBJECTIONS

Will this operation be followed by adhesions? Without question every operation which opens the peritoneal cavity is followed by adhesions. They are temporary and cause no trouble. One of these operative areas has been inspected at a second operation about twenty days later. A filmy remnant at the lower edge was all that remained of the adhesions. The patch was accurately and solidly in place. The omentum was alive and normal. There has not been the slightest trouble from adhesions so far and we regard the danger as negligible.

Will such patches frequently develop infections and be discharged? We are sure they will not. Of the 84 patches reported here, 2 were discharged, in the presence of a slight infection. The case was one of a double strangulated hernia and each incision traversed a dirty infected

ulcer caused by branding. Every effort was made to clean up these ulcers before the operation, but a low grade infection set in and the patches were discharged. Barring this case, the patches have healed in faultlessly.

The asepsis in this series was not perfect. There were 3 slight skin infections. Two resulted from skin sutures left in for twelve days. The third was a report from home that a silk suture had been discharged. There were a number of small hematomas. In all of these cases the patches healed in perfectly.

SUMMARY

1. Experience in Arabia would indicate that the essential pathology of inguinal hernia is weakness in the fibrous investment of the parietal peritoneum. At such a point the intra-abdominal pressure produces a hernia.

2. Patches of preserved ox fascia applied to the weak area from within the peritoneal cavity make easily possible the permanent cure of both direct and indirect simple hernias.

3. Granted an aseptic technique of reasonable precision, the use of these patches is extremely easy and simple.

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SPASM OF THE LAST ILEAL LOOP SIMULATING REGIONAL ILEITIS

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INTEREST in regional ileitis, first conceived as a clinical entity by Crohn, Ginzburg, and Oppenheimer,[1] is growing each year, as indicated by the numerous reports in the literature. There are, however, many unsolved problems, both pathologic and clinical. Thus, little is known at present about the diagnosis of the early stages, of the problems of spontaneous regression, of the relative merits of conservative and radical treatment, of the value of appendectomy, and of the differential diagnosis between spastic conditions and mesenteric lymphadenitis and lymphangitis.

The early case of regional ileitis presents a difficult diagnostic problem. There is usually some intermittent vague pain in the right lower abdomen with slight diarrhea with or without nausea or vomiting. X-ray findings are atypical and are subject to various interpretations. Even on operation in such early cases it is not possible to palpate or to determine pathologic changes, so that transillumination may be necessary to detect ulcerations of the inner surface of the ileum. Dixon[2] reports two such cases in which nothing was found at operation despite x-ray indication of regional ileitis but which showed at autopsy definite ulceration within the last ileal loop.

These pathologic changes ordinarily constitute a progressive process, although the rate of progression and the degree of its continuity vary considerably from patient to patient. Spontaneous regressions may occur, but whether these regressions are permanent is, as yet, not known. Rockey[3] reported four patients in whom only appendectomies were performed and all were symptom free one to six years later. Probstein and Gruenfeld[4] performed an enterostomy in an acute case and three months later, when the enterostomy was closed, biopsy of the previously diseased ileum was microscopically normal. Similar observations were made by others.

Recently, we observed three cases in which were encountered the diagnostic problems that early or questionable cases of regional ileitis present. The following case, which we have studied most intensely and which we have followed for about a year, affords the opportunity of comparing the clinical and roentgenologic findings with the condition found at operation.

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CASE HISTORY

Miss I. W., aged 19 years, was first seen on July 7, 1938, complaining of colicky lower abdominal pain for two days. Similar attacks of variable duration had recurred intermittently for the past two years, occasionally associated with nausea but never with vomiting. These attacks were entirely unrelated to type of food eaten or time of eating, to menstruation, or to bowel habits; but, when present, they would be aggravated by physical exertion. Systemic inquiry was negative except for a vague history of a diarrhea of one day's duration preceding the initial attack two years previously. Physical examination was completely negative except for some slight tenderness without rigidity over the right lower abdominal quadrant. Temperature was normal and the blood count showed 90 per cent hemoglobin, 4,620,000 red cells, and 8,820 white cells with 68 per cent polymorphonuclear leucocytes and 32 per cent lymphocytes. Stool examinations and urinalysis were negative.

Fig. 1.—The distal ileal loop shows marked narrowing (string sign) and a disturbed mucosal pattern strongly suggestive of a regional ileitis.

Clinically, the picture was suggestive of some atypical, low grade appendical pathology, but, because of the vagueness of the complaints and findings, gastrointestinal x-ray study was made.

Barium administered by enema visualized the appendix, located between the last ileal loop and the cecum. The distal ileal loop presented a marked narrowing (string sign) and a disturbed mucosal pattern strongly suggestive of a regional ileitis (Fig. 1). Five days later barium was administered orally. The upper gastrointestinal tract was normal, but the distal ileal loop again showed marked contraction and unusual arrangement of the ileal loops in a winding manner from the pelvic aperture up to the cecum (Fig. 2).

Because of the marked disparity between the roentgenographic findings and the symptoms, rest and antispasmodics (phenobarbital and belladonna) were prescribed. Two weeks later the patient was again studied by x-ray. Rectally administered barium showed the cecum well distended and well rounded. The ileocecal valve opened easily so that the barium overflowed into the ileal loop, which appeared to be normal. The contractions previously noted were no longer discernible. (Fig. 3.)

One month later the patient was hospitalized for further study because of recurrent pain. An appendectomy was performed through a muscle-splitting incision.

Fig. 2.—The distal ileal loop shows marked narrowing and unusual arrangement of the ileal loops in a winding manner from the pelvic aperture up to the cecum.

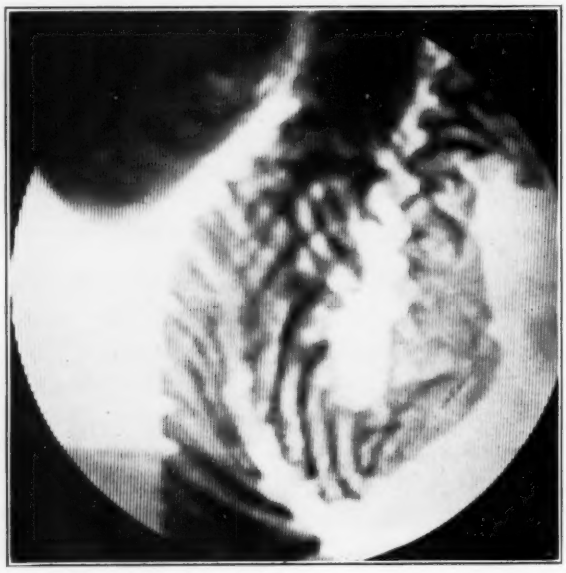

Fig. 3.—Normal appearing ileum following antispasmodics and sedatives.

The distal ileum, cecum, and first part of the ascending colon were grossly normal and the appendix showed a long fecalith at its proximal portion. There was a constriction of the lumen about 15 cm. from the appendical tip which did not admit a fine probe and distal to this constriction the lumen was patent. Distal to the constriction, the mucosa was clean, pearly white, and somewhat edematous. Microscopically, the mucosa appeared edematous and hyperemic and showed moderate cellular infiltration. The serosa was somewhat thickened and edematous.

Recovery and convalescence were uneventful. While the patient was symptom free, five months after operation she was submitted to further x-ray study to determine the status of the distal ileum, and, although it was within normal limits, there was some suggestion of a slight degree of spasticity with irregular mucous folds.

COMMENT

This patient presented roentgenologic findings strongly suggestive of an acute regional ileitis, but the clinical symptoms were vague. The well-advanced case of regional ileitis that presents classical findings, including bloody diarrhea, roentgen evidence of filling defects, and fistula formations, offers no diagnostic problem relative to the presence of true pathologic changes of the involved bowel. When, however, the patient's complaints are those of mild recurrent right lower abdominal colicky pain associated with such roentgenologic findings, as present in this case, the diagnosis is not so apparent.

Since physicians have become so conscious of regional ileitis, it is well to remember that the last ileal loop is very frequently the location of long-standing, reflex spastic conditions, which clinically and sometimes roentgenologically simulate regional ileitis. Thus, if some of the cases which are reported as cures following appendectomy or other forms of conservative therapy are studied, their classification under the well-defined entity of regional ileitis becomes doubtful.

If the ileal contracture responds to sedatives and antispasmodics, it is evident that the condition is not a true ileitis but rather a reflex spasm and, as such, may be associated with spasm of the colon. The occurrence and frequency of spastic conditions along the gastrointestinal tract are commonly known, but their differentiation from organic pathologic changes is still the greatest source of error for the roentgenologist and clinician.

Such spastic contractures are seen in the normal colon in the physiologic sphincter areas, as the ileocecal sphincter of Varolius, the cecum-sphincter of Busy, the ascendens sphincter of Hirsch above the ileum, the transversum sphincter of Cannon, the splenic flexure sphincter of Peyer, the descendens and sigmoid sphincter of Balli, the middle sigmoid sphincter of Moutier and Boosi, and the rectosigmoid and rectal sphincter of Moutier. Another example of such spasticity is the spastic contracture noted on the side opposite to a duodenal or gastric ulcer. Many old textbooks mention, under the subject of appendicitis, the contraction of the last ileal loop, which may be palpated through the abdomen.

Other sources of irritation, local or distant, are kidney stones, ectopic kidneys, inflamed mesenteric lymphadenitis, and gallstones.

We are convinced that there are many more instances of spastic conditions of the bowel without local anatomic lesions than instances of true regional ileitis. Galambos and Mittleman[5] concur in this belief. If, therefore, regional ileitis is to be considered as a distinct entity, these spastic conditions must be differentiated. The string sign must be considered as representing the maximal contraction of the colon of spastic origin and is neither characteristic nor pathognomonic of regional ileitis. It may be present in any spastic condition of the bowel. Kantor,[6] whose name is attached to the string sign, emphasizes this fact and recommends, therefore, repeated and prolonged observations in these cases. In our cases the response to sedatives and antispasmodics preoperatively clearly suggested a spastic rather than a proliferative phenomenon.

The most marked contraction roentgenologically observed by us (J. A.) was in a patient in whom the spastic condition was superimposed upon a mild colitis (Fig. 4). After several weeks of bed rest and antispasmodic medication, the colon regained its normal width and haustration.

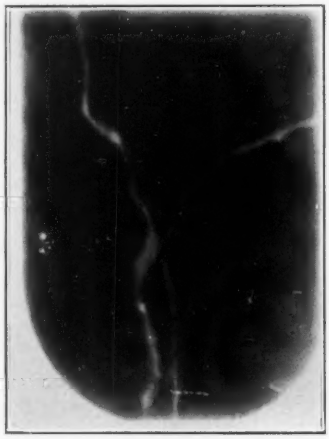

Fig. 4.—Severe spasticity of the colon.

Ileal spasm may be a vagotonic manifestation with a lowered threshold of reaction, and emotional factors or generalized nervous conditions may be responsible. In certain cases the appendix may prove to be the irritating factor, even though it may show no histologic evidence of inflammatory change. Two of our cases presented grossly what may be called mechanical appendices in that the lumen was in some measure obstructed. Observation in one of these cases leads us to believe that an appendical fecalith may cause reflex spasm of the terminal ileum, and, when the fecalith is spontaneously extruded into the bowel, the symptoms and spasm may quickly subside. In this reported case ob-

struction and low grade inflammation of the appendix were both present. While one must be conservative in regard to routine appendectomies in these cases of ileal spasm, when all other causes, emotional and physical, can be ruled out, we feel that the appendix should be removed and examined carefully.

Undoubtedly, some of the reported cases of spontaneous regression in acute regional ileitis were not instances of true regional ileitis but rather belonged in the category of spastic ileitis. Preoperative antispasmodic medication might have established the true nature of the case, as it did in this instance. It is our firm belief that routine gastrointestinal x-ray study in clinical cases of subacute or chronic appendicitis may reveal more instances of such spasm. Whether or not this condition is a forerunner of true ileitis at present cannot be stated. However, this hypothesis is conceivable because such spasm and resulting stagnation of intestinal contents enhance the possibility of bacterial growth with invasion of the mucosa and the lymph nodes and subsequent proliferation.

CONCLUSION

A condition which may be termed reflex spastic pseudoileitis is described, consisting of a contraction of part of the ileum which can be readily demonstrated roentgenographically. It is often difficult to differentiate the early case of true regional ileitis from such spastic conditions which are much more common. The string sign is of little differential value because it represents the visible roentgenologic evidence of the spastic contraction, which may or may not be superimposed upon some organic localized lesion. However, the mildness of clinical symptoms and the response to sedatives and antispasmodics are diagnostic of the spastic condition and, although the causes of this spasm may be multiple, the appendix should be considered.

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ACUTE SOLITARY DIVERTICULITIS OF CECUM

Report of a Case

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(From the University of Western Ontario)

THE condition of acute inflammation of a solitary diverticulum of the cecum appears to be comparatively rare, for published case records are few and far between in the main. The most comprehensive article available on this subject is that by Bennett-Jones; in 1937 he described three cases encountered in Liverpool as well as presenting summaries of seventeen previously chronicled examples. Undoubtedly some instances have been overlooked, as that given by Pessagno, but in all the number of recorded cases is small. I have been fortunate enough to meet two examples of this lesion in my own practice in the last two years (the first has been reported already). There are valid grounds for a belief that this little known entity, barely mentioned even in most of the accepted surgical textbooks, cannot be truly as infrequent as its reported incidence might imply. This view demands more general recognition of the process as well as publication of the salient features of each attested case.

The manifestations, in no wise distinctive, are simply those of an inflammatory process in the right lower abdomen; the acuteness and intensity vary widely. There is no wonder that the diagnosis is commonly confused with that of the commonest of all abdominal emergencies. Lack of familiarity with the condition, together with the unusual findings at operation, after careful search following discovery of a relatively innocuous appendix, has too often in the past led to performance of an ill-judged surgical procedure. In my own first case the inflammatory mass was situated in the posterior cecal wall and was inaccessible to full examination; the characters strongly suggested a malignant neoplastic process, while a group of moderately enlarged tuberculous glands in the terminal region of the mesentery further simulated a carcinoma with glandular metastases. A right hemicolectomy proved successful, although drastic, treatment. Several recorded cases have met the same operative management on account of inability of the operator to identify the disorder.

CASE REPORT

The patient was a single, white female, aged 37 years. I saw her first at her home on Jan. 18, 1939.

History.—She stated that there had been pain localized to the right lower quadrant of the abdomen for about fifty hours. Previous to that she had felt well but had

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noticed some failure of appetite for two days. The pain was spasmodic in character primarily but became dull and aching in type while seeming to be related intimately to the anterior abdominal wall. (At a later date it was admitted that the pain was very severe, preventing sleep the last night, along with a persistent fever as high as 103° F.) With the attack there was constipation. There was neither nausea nor vomiting.

During the preceding two years there had been several bouts of transient pain in the right lower abdomen; curiously enough, these had occurred only on certain occasions when she was riding horseback. In the last six months there had been loss of six pounds in weight, and friends had remarked that she was not looking well. Subjectively she had felt "always tired" for some time.

Physical Examination.—The general state was satisfactory with her lying in bed. Movement caused complaint of discomfort over the right iliac fossa. Pulse rate, 98; temperature, 99.4.

The abdomen presented a normal contour with moderate respiratory excursion. Palpation revealed a deeply located small mass approximately one inch below McBurney's point. This was tender to pressure, but without any overlying muscular rigidity. The remaining findings were essentially normal, including the rectal examination.

Hospitalization was effected without delay, the presumptive diagnosis being acute appendicitis. I pictured a barrier of inflamed omentum intervening between the offending viscus and the parietal peritoneum.

Operation.—Through a muscle-splitting incision the appendix was exposed at once; it was normal apart from a little superficial hyperemia. In the front wall of the cecum, close to the ileocecal junction, I demonstrated a thickened, indurated zone, covered by a thin layer of fibrinous deposit. This mass, with characters previously described by me as like the firm "yolk of a fried egg," was situated actually within the wall of the bowel. Its identity was apparent to me immediately, chiefly on the basis of former experience with the condition. A wedge type of local resection was carried out, one angle of the wedge encroaching on the ileocecal valve to a marked degree. Exploration of the adjoining abdominal organs through a slightly extended incision brought no further abnormalities to light. There were no enlarged mesenteric glands. The wound was closed in layers with superficial drainage.

The postoperative course was comparatively smooth, although for some days there was complaint of crampy pain in the cecal region along with exaggerated borborygmi. No doubt this was the result of partial interference with bowel conduction at the edematous ileocecal stoma. The bowels moved first on the third day, and normally thereafter with some assistance. The wound healed perfectly and all symptoms disappeared completely at an early date. She was discharged from the hospital on the tenth day.

When last seen six months later the patient was entirely well and free from symptoms.

The chief pathologic features are illustrated in Figs. 1 and 2 and are summarized in the legends.

This case exemplifies the difficulty that may attend identification of emergency conditions located in the right lower abdomen. It bears out the statement that the abdomen is a "mystery box"; many puzzles can be solved only after the "lid" has been lifted, and not easily in every case even then. The importance of familiarity with unusual

abdominal lesions on the part of all engaged in surgery is illustrated. It might be interesting to speculate on the mechanism of production of repeated bouts of right lower quadrant pain in the case presented on certain occasions when she was riding horseback. No doubt the

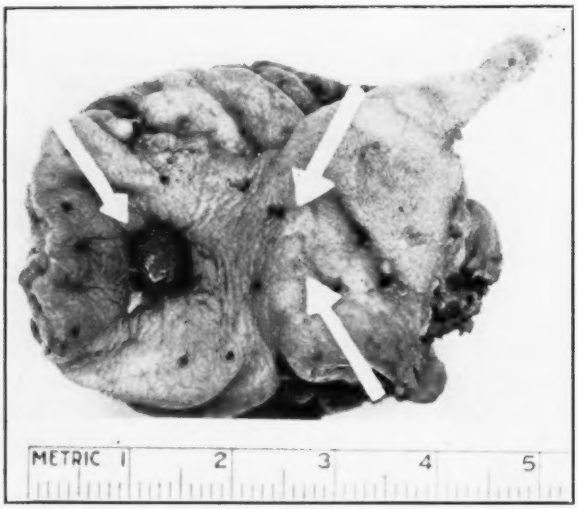

Fig. 1.—Acute solitary diverticulitis of cecum, mucosal surface. The orifice of the diverticulum is indicated by the arrow on the left; an obstructing fecolith is evident. The arrows on the right-hand side mark the margin of the ileocecal valve, a large part of which has been removed. The ring of dark spots about the diverticulum is the result of the specimen's having been pinned down during fixation. (This photograph, as well as Fig. 2, was kindly taken by Dr. J. Fisher, Professor of Pathology, University of Western Ontario.)

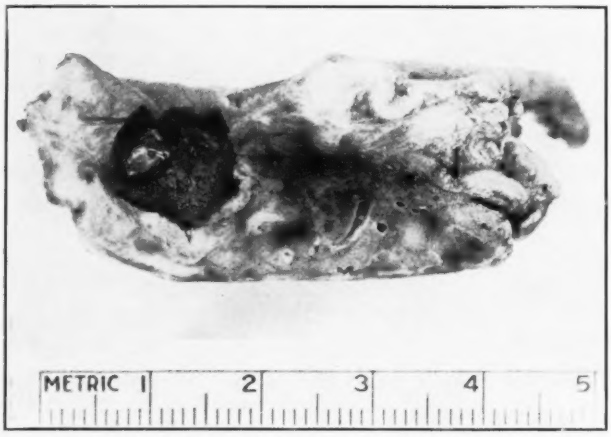

Fig. 2.—Acute solitary diverticulitis of cecum, sectional view. A longitudinal section of the specimen illustrated in Fig. 1 is shown. On the left the diverticulum is seen with its cavity plugged with inspissated fecal matter; the fecolith has been displaced a little from the actual ostium. The divided ileocecal valve can be discerned 1 cm. to the right of the diverticulum. The inflammatory thickening of the bowel wall is striking. In the section it is possible to distinguish the muscular coat and the fact that this is interrupted abruptly at the margin of the diverticular sac. The diverticulum is obviously "false" in type, extending through a muscular hiatus. The subserous tissues are particularly involved in the inflammatory process, appearing "thickened, edematous, soft and grayish in color, obviously a mass of inflammatory tissue. The serous surface presents a thin film of grayish exudate."

presence of the fecolith was of importance in this regard, perhaps becoming temporarily impacted in the orifice. Such fecal concretions play a leading role in determining the course of the inflammatory process in cases that have been recognized eventually. Detailed studies of post-mortem material for the true incidence of cecal diverticula uncomplicated by inflammation might furnish valuable information. Greensfelder and Hiller have shed some light on the occurrence of a traumatic or secondary type of cecal diverticulosis as found in operations and autopsies on adults. The true incidence of the primary condition appears to be quite unknown. It is well established, as reemphasized recently by Dixon and co-workers, that intestinal diverticula assume importance only when they are causing symptoms. Acute inflammatory complications are particularly prone to arise and to provide disturbing clinical problems.

SUMMARY

A case of acute solitary diverticulitis of the cecum, the second in my experience in two years, is reported. Certain aspects of this condition are recalled, giving thought particularly to recognition and therapeutic management.

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INTERLOBAR PERFORATED ABSCESS OF THE LUNG (INTERLOBAR EMPYEMA)

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BY INTERLOBAR empyema is meant a collection of pus situated between two pulmonary lobes and shut off from the free pleural space. In the older literature many features of the lesion were described, such as its rarity, high mortality, difficulties in diagnosis and in the disclosure of pus by exploratory aspiration, and the danger of infection of the general pleural cavity at operation.

This precise clinical evaluation of the lesion no longer holds at the present time. References to interlobar empyema in recent literature indicate a widely held impression that the lesion not only is of frequent occurrence but also is of no special moment. The diagnosis often is made on the basis of roentgenograms of effusions in the region of fissures. Any encapsulated collection of pus encountered at operation over an interlobar fissure is apt to be classified as an interlobar empyema regardless of whether or not it is situated in part or in whole between two pulmonary lobes. Were our criticism merely one of a loose use of terms, the reopening of an old subject would not be justified. However, some features of the pathology, of the roentgenology, and of the surgical treatment of true interlobar suppuration have important clinical implications according to our observations. A reconsideration of the subject appears warranted for these reasons.

Throughout this paper we shall adhere to the precise definition of an interlobar empyema as one entirely limited to the space between two lobes. In an examination of the records of 650 cases of empyema treated at the Mount Sinai Hospital in the past ten years, only sixteen cases of unquestionable interlobar collections of pus were encountered. There were a number of instances of empyemas in the region of fissures or dipping into fissures which will not be included. This paper is based on an analysis of the sixteen cases of proved interlobar suppuration.

PATHOGENESIS, PATHOLOGY, ETIOLOGY

In every proved instance the collection of pus was situated definitively between two lobes and was more or less completely enclosed by those lobes. Interlobar collections of pus were situated at various depths. In a few cases parietal adhesions were scanty or absent, the lesion being enclosed completely between the lobes. In the majority of the cases, the

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periphery of the interlobar abscess was close to the parietal pleura. As a result, overlying parietovisceral pleural adhesions were present in most instances. Although their extent and degree varied, these walling-off adhesions sufficed in most instances for surgical entry of the interlobar abscess without entry of the free pleural cavity. That this was not always achieved was due to faulty interpretation of the site of parietal adhesions.

The outstanding and constant feature of the pathology of interlobar suppuration, as revealed at operation or in the postoperative course, was a perforated abscess of the lung. The actual pulmonary cavity, situated immediately beneath an interlobar surface and communicating with the interlobar space via the rupture, was visualized in all but one case (Case 13). The pulmonary abscess was of substantial proportions in most instances. Almost invariably one or more orifices of bronchi were to be seen in the wall of the pulmonary cavity. Such bronchial fistulas were noted either at the time of operation or during the postoperative course. Their presence, the superficial, albeit interlobar, situation of the pulmonary abscess, and the overlying interlobar pleural adhesions, all indicate that the pulmonary abscess which was the cause of the interlobar empyema was of bronchogenic and not of hematogenous origin. The greater incidence of putrid (anaerobic) as compared with nonputrid (aerobic) abscess is noteworthy. Thus, there were thirteen cases of perforated putrid abscess of the lung and three cases of perforated nonputrid abscess of the lung. In only one instance of putrid interlobar empyema (Case 13) was a perforated pulmonary abscess not demonstrable. The case is included in this series because, as shown elsewhere,[2] the etiology of putrid empyema is usually, if not invariably, an underlying putrid pulmonary abscess. In any event, there can be no doubt as to its inclusion in this particular case since foul pus was expectorated upon one occasion.

A perforated pulmonary abscess, most commonly putrid, is thus the cause of so-called interlobar empyema according to our studies, and the correct term for the lesion therefore is interlobar perforated pulmonary abscess. The number of cases is too small to warrant any conclusions as to the etiology of the underlying pulmonary abscess. The proportion of putrid to nonputrid abscesses is about the same as that for abscesses elsewhere in the lung.[3] There is the same high proportion of putrid abscess without known etiology in patients with poor oral hygiene, to which attention has been called elsewhere.[4, 5] One may, therefore, assume that the etiology of a pulmonary abscess is the same whether the lesion faces a fissure or is the usual variety superficially situated elsewhere in the lung.

CLINICAL MANIFESTATIONS, DIAGNOSIS

The clinical manifestations of perforated interlobar abscess are not distinctive and, therefore, offer no lead to the correct diagnosis. They suggest a pneumonic lesion, with fever, cough, and varying degrees of

thoracic pain. Expectoration of foul pus occurred in most of the cases in which a putrid pulmonary abscess existed. In comparison with the usual course of empyema, in which the acute pneumonic stage is followed by the milder picture of postpneumonic empyema, the course of interlobar ruptured pulmonary abscess was severe and sustained. The picture often was that of a persistent and profound toxemia.

The physical signs were of no distinctive value in the diagnosis, being either those of consolidation or those of fluid.

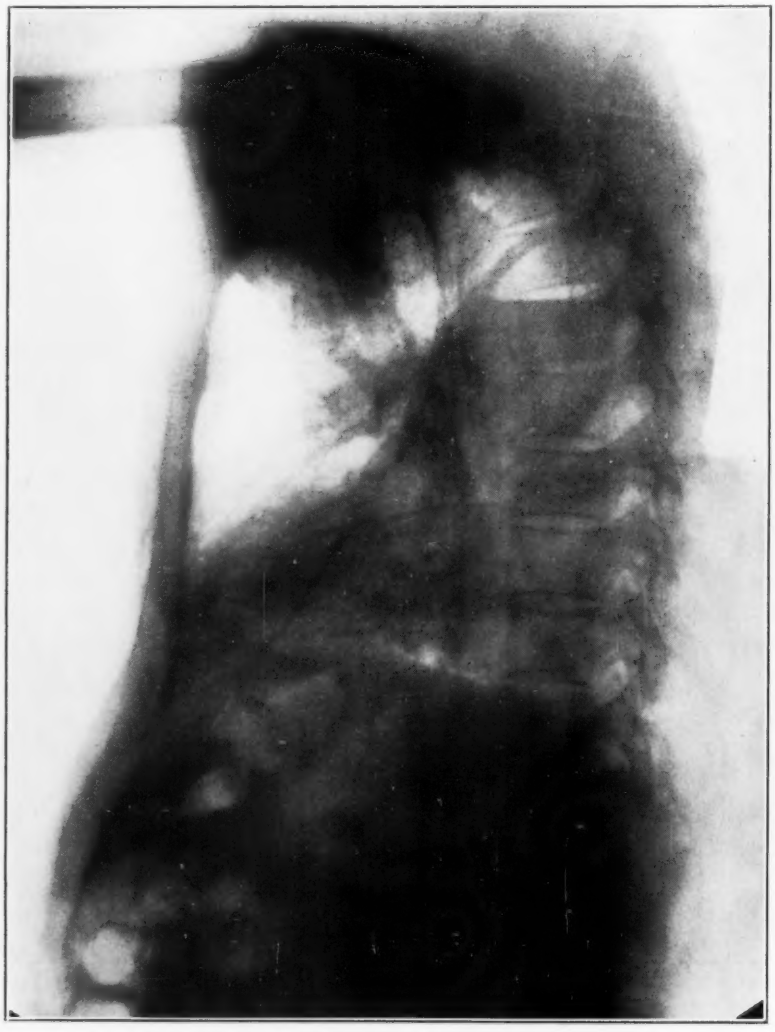

Fig. 1.—(Case 3.) Characteristic loculation of fluid and air within the long fissure.

The diagnosis can only be based on the roentgen features. It may be stated at once that the correct diagnosis was not made in the majority of cases. As a result, some patients were subjected to repeated exploratory aspirations before pus was encountered. Furthermore, operations for drainage were performed at incorrect sites and through the free pleural cavity in some instances; whereas, the surgical approach might have

been placed over the site of pleural adhesions. The imperative necessity of correct diagnosis and precise localization by roentgenographic study is emphasized by the complications which occurred and the fatalities which could or might have been avoided.

The differential diagnosis between a ruptured and an unruptured pulmonary abscess facing the fissure is difficult and may be impossible. The etiology, clinical manifestations, and physical signs are identical. A typical unruptured abscess facing an interlobar fissure presents distinctive roentgenologic features. However, its recognition may be no longer possible in the presence of a pronounced pleural reaction about the abscess. Since the treatments of a perforated interlobar abscess and one on the verge of perforation are the same, the question of differentiating between the two is only of theoretical interest.

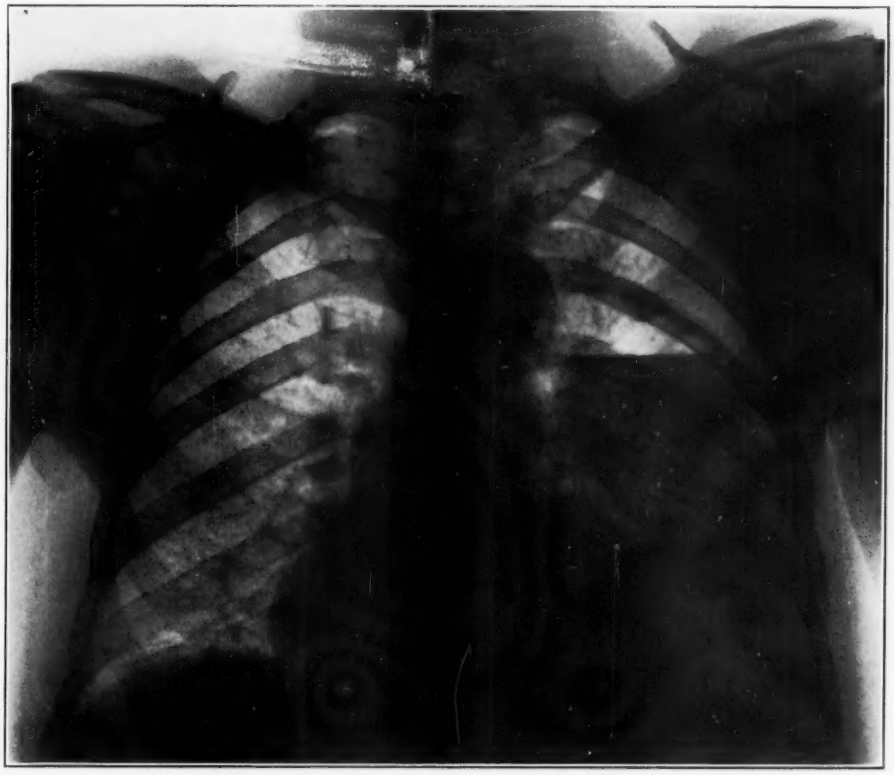

Fig. 2.—(Case 3.) Same case as shown in Fig. 1, film taken at the same time. Lesion not recognizable as such in the posteroanterior view.

ROENTGENOGRAPHIC FEATURES

The roentgenographic characteristics of the normal fissures are well known. Their anatomical features should be outlined because the localization of the interlobar collection of pus in relationship to the situation of an interlobar fissure is essential for correct diagnosis.

The long interlobar fissure extends obliquely downward and forward from the level of the second dorsal spine to the sixth costochondral junc-

tion. On the right side the short fissure starts from the long fissure in the midaxillary line and follows the course of the fourth rib, assuming a more or less horizontal plane as it meets the general pleura anteriorly. The interlobar spaces are bounded on the right side by the upper and lower lobes posteriorly and superiorly, by the upper and middle lobes anteriorly, and most anteriorly, but on a lower level, by the middle and lower lobes. There is only one interlobar fissure on the left side, if no congenital abnormalities are present.

When normal, the fissures are not seen in the x-ray film. However, the anterior extremity of the short fissure may be visualized accidentally if the central ray is parallel with it.

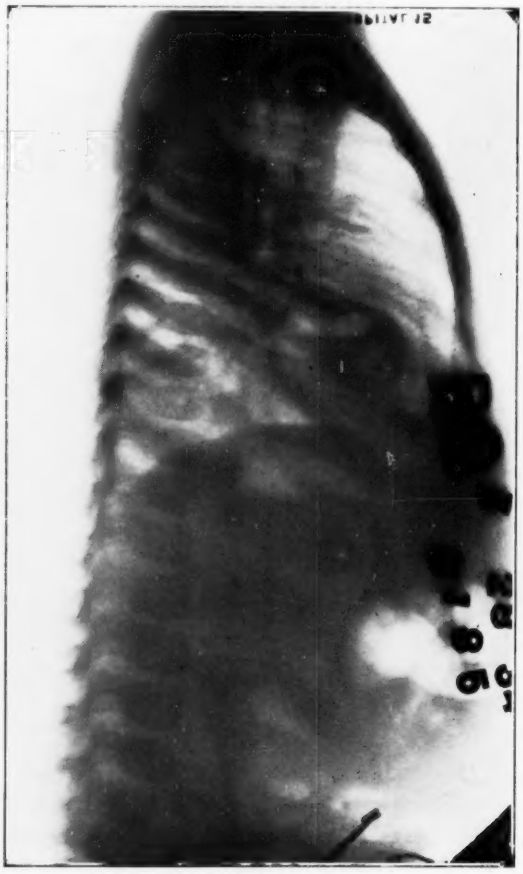

Fig. 3.—(Case 4.) Collection of fluid and air in or at the fissure. At operation, interlobar pyopneumothorax.

Roentgenologic signs of interlobar pleuritis are easily identified in lateral views of the thorax. They are more difficult of interpretation in the posteroanterior views, when they may be mistaken for parenchymal infiltrations, particularly if located near the hilus.

An unencapsulated serous interlobar effusion may be recognized without great difficulty. It occurs in a flat elliptical form with its long axis

in the plane of the known location of the fissure. Since there is little, if any, exudate over the pleura bounding sterile effusions, extension beyond the fissure and into the general pleural space is prone to occur. Effusions of moderate extent in the general pleura may dip into the interlobar spaces. Under the latter circumstances, the presence of fluid in or out of the fissure depends, roentgenologically speaking, on the position of the patient.

The roentgenologic appearance of interlobar purulent exudates differs from that of nonsuppurative effusions because of the underlying pathologic differences. The features of the pathology of perforated interlobar abscess which are of roentgenologic interest can be reiterated briefly. The intense reaction of the pleura about a perforating lung abscess agglutinates apposed pleural surfaces. This serves to wall off the abscess

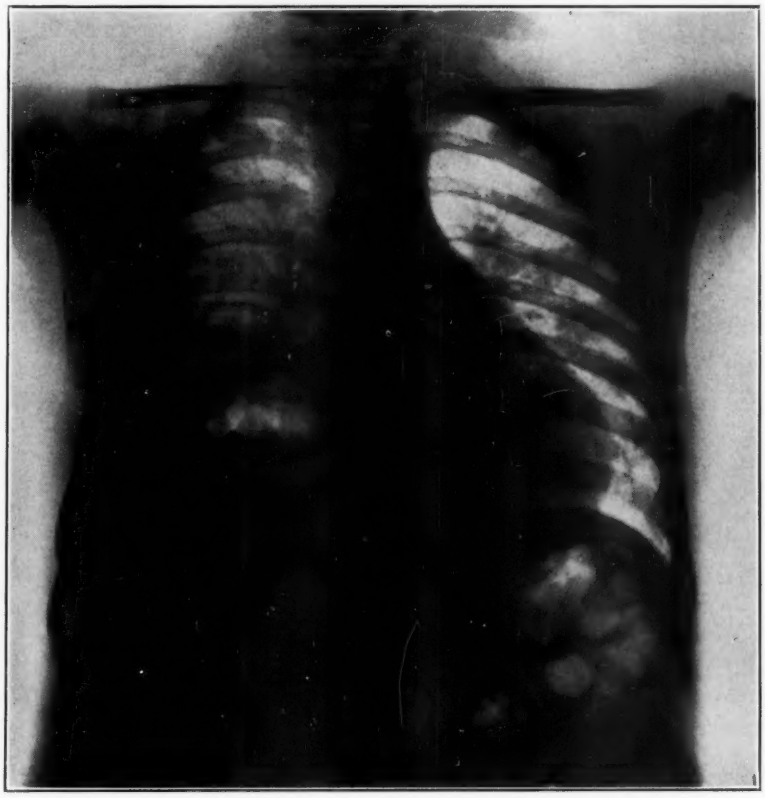

Fig. 4.—(Case 4.) Same case as shown in Fig. 3, posteroanterior view, which is not characteristic.

and prevent its spread beyond the interspace unless perforation occurs very suddenly. The pleural exudate may be so thick that a small underlying lesion in the lung will be obscured and so sharply circumscribed and deep within the hemithorax that a primary parenchymal neoplasm may be simulated.

The sixteen cases on which this paper is based can be divided into those with roentgenologic evidence suggesting an interlobar lesion, and those in which such a lesion cannot be identified in the x-ray film.

In nine cases (56 per cent) the diagnosis of an interlobar lesion could be made or suggested by a study of the roentgenograms. They can be classified as follows:*

Fig. 5.—(Case 7.) Bowing of the short fissure due to interlobar fluid. Exudate within the long fissure.

A. *Interlobar Effusion.*—

CASE 1.—An interlobar effusion on the left side was identified in the roentgenogram. At operation, an interlobar collection of pus was entered and a small bronchopulmonary fistula was encountered.

CASE 2.—There was an oval shadow in the film of the right chest extending from the third rib to the level of the diaphragm. This was thought to be an effusion in

*The case numbers correspond with the numbers of the case reports summarized in Table I.

the main interlobar fissure. At operation, a large amount of purulent fluid was evacuated from the interlobar space. The orifice of a perforated pulmonary abscess was found on the under surface of the upper lobe.

B. *Interlobar Pyopneumothorax (Fluid Level Within a Fissure).*—

CASE 3.—In the film there were two loculations on the left side. The larger, containing air, was situated in the interlobar fissure; the smaller was located in the posterior axilla. Operation disclosed the larger to be interlobar, and the smaller to be infrapulmonary. A perforated putrid abscess was found on the under surface of the upper lobe.

CASE 4.—The roentgenologic evidence suggested a right interlobar pyopneumothorax. Operation confirmed the diagnosis and demonstrated the source of infection to be a small perforated abscess on the interlobar surface of the lower lobe.

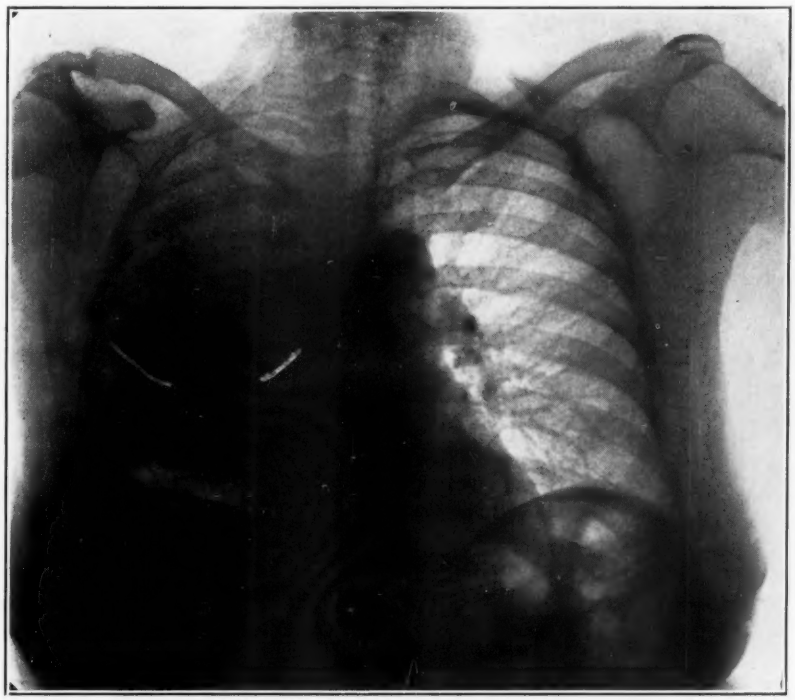

Fig. 6.—(Case 7.) Posteroanterior view of same case as shown in Fig. 5. Retouched film.

C. *Fluid Level On or Near a Fissure.*—

CASE 5.—In the x-ray film there was an area of infiltration in the apical portion of the left lower lobe, within which were two fluid levels, the larger being situated near the interlobar fissure. A large interlobar collection of foul pus was found at operation. The perforated focus, facing the fissure, was in the apical segment of the left lower lobe.

CASE 6.—Two fluid levels in the anterior portion of the right chest were seen in the film. One, on the fissure, was thought to be in the pleura, and the other in the lung. An interlobar collection of foul pus was evacuated at operation. Because of the poor condition of the patient, a perforated abscess was not sought.

D. *Alteration of the Fissure.*—

CASE 7.—There was a large anterior loculation bowing the short fissure, with convexity downwards. At operation, an interlobar collection of foul pus was evacuated from the long fissure.

E. *Progression of Disease Along a Fissure.*—

CASE 8.—An operation was performed which consisted in drainage of a putrid abscess in the axillary portion of the upper lobe. Subsequently, roentgenograms suggested extension of the disease along the fissure from the right middle lobe to the upper lobe. A second operation unroofed a new abscess and an interlobar empyema which was derived from a perforated abscess of the upper lobe.

Fig. 7.—(Case 8.) Bowing of midportion of long fissure. Apparent extension of infection to the surface of the upper lobe. Interlobar collection of pus found at operation.

F. *Sharply Circumscribed Pneumothorax.*—

CASE 9.—The roentgen film showed a sharply circumscribed pneumothorax in the middle third of the right lung. Above and mesial to this, there was a dense shadow suggesting a compressed upper lobe. A lateral film was not taken. Operation disclosed a putrid interlobar pyopneumothorax.

COMMENT ON CASES WITH DISTINCTIVE ROENTGENOLOGICAL FEATURES

In the foregoing nine cases the roentgenologic evidence of an interlobar lesion was either characteristic or suggestive.

In four instances a definite interlobar collection of fluid or fluid and air was visible. Another case showed a sharply circumscribed pneumothorax in the middle third of the lung field. The evidence was presumptive in the remaining cases. In two there was a fluid level at or near a fissure. One case showed a bowing of a fissure, and the films of another suggested progression of disease along a fissure.

The evidence of depression of a fissure, the presence of a fluid level at or near a fissure, and even a fusiform shadow in the location of a fissure are not infallible signs of interlobar lesions. Cases have been observed in which these features were noted in the absence of an interlobar lesion.

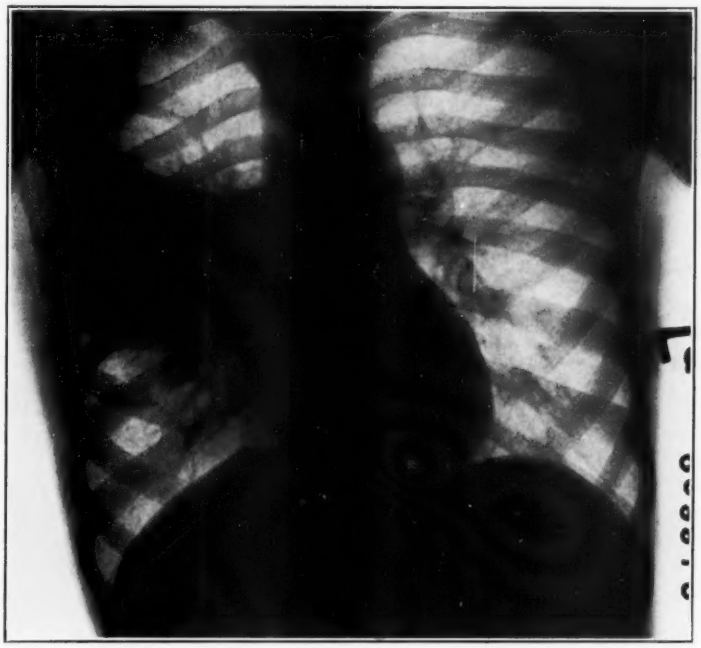

Fig. 8.—(Case 8.) Posteroanterior view of same case as shown in Fig. 7. The existence of an empyema is not suggested by this film.

The seven cases (44 per cent) in which there was no roentgenologic evidence of interlobar disease do not fall into groups. They can be summarized as follows:

Case 10 showed a large pleural effusion. Only bloody fluid was obtained by aspiration of the general pleura, but aspiration at a greater depth disclosed foul pus. At operation the source of the interlobar empyema was a perforated abscess on the under surface of the upper lobe.

In Case 11 several areas of translucency were seen through the massive left pleural effusion. Operation disclosed a large interlobar empyema, the source of which was a ruptured abscess on the superior aspect of the lower lobe.

In Case 12 the roentgenogram revealed a suggestive fluid level in a large right posterolateral effusion. Multiple loculations in the long fissure and a bronchial fistula on the inferior surface of the upper lobe were found at operation.

Case 13 showed roentgenologic evidence suggesting a loculation of fluid in a case diagnosed clinically as a left lower lobar pneumonia. Aspiration yielded foul pus, and operation uncovered an interlobar empyema.

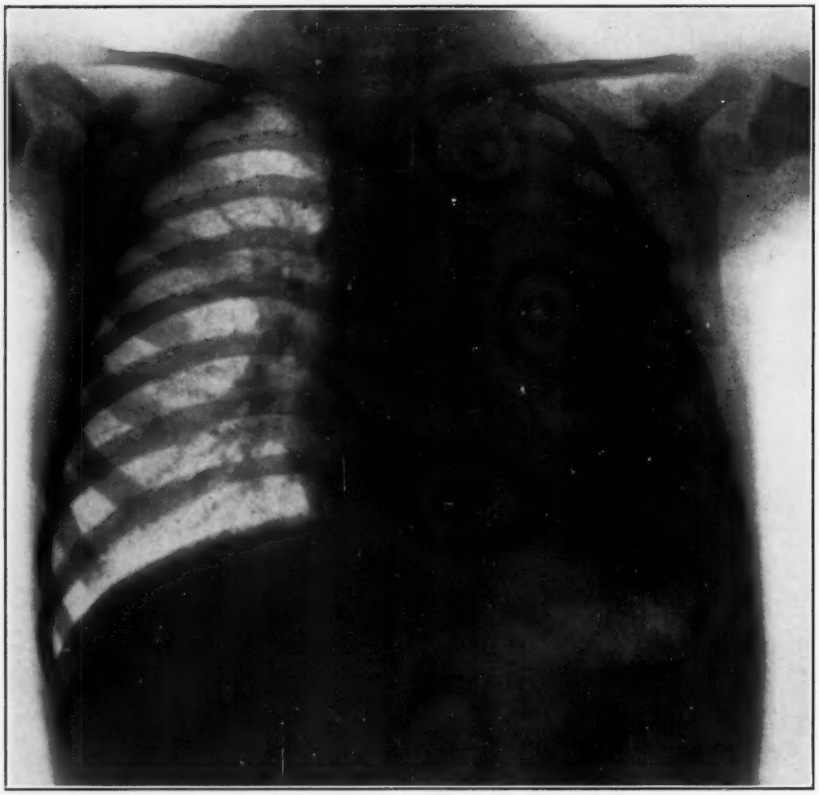

Fig. 9.—(Case 11.) Areas of translucency within a generalized pleural effusion.

In Case 14 a pleural exudate was noted in the posterolateral aspect of the midportion of the right chest. There was suggestive evidence of several cavities above the area of exudate. An empyema between the upper and lower lobes was found at operation; its source was a large perforated abscess on the under surface of the upper lobe.

In Case 15 there was a partial collapse of the right lung, with a suggestion of an excavation in the upper lobe. A sharply circumscribed dense lesion was also noted in the upper lung field. At operation, a putrid pyopneumothorax was found localized between the two lobes on the posterior aspect of the long fissure. The cause was a ruptured abscess of the upper lobe. The circumscribed lesion in the upper lung field was found subsequently to be a periapical empyema.

The roentgenogram in Case 16 revealed a sharply circumscribed lesion about two inches in diameter in the lower lung field. Its x-ray appearance was strongly suggestive of the peripheral variety of carcinoma of the lung. Aspiration yielded foul pus. At operation a small interlobar empyema was uncovered and a bronchial fistula was demonstrated in the upper lobe, facing the fissure.

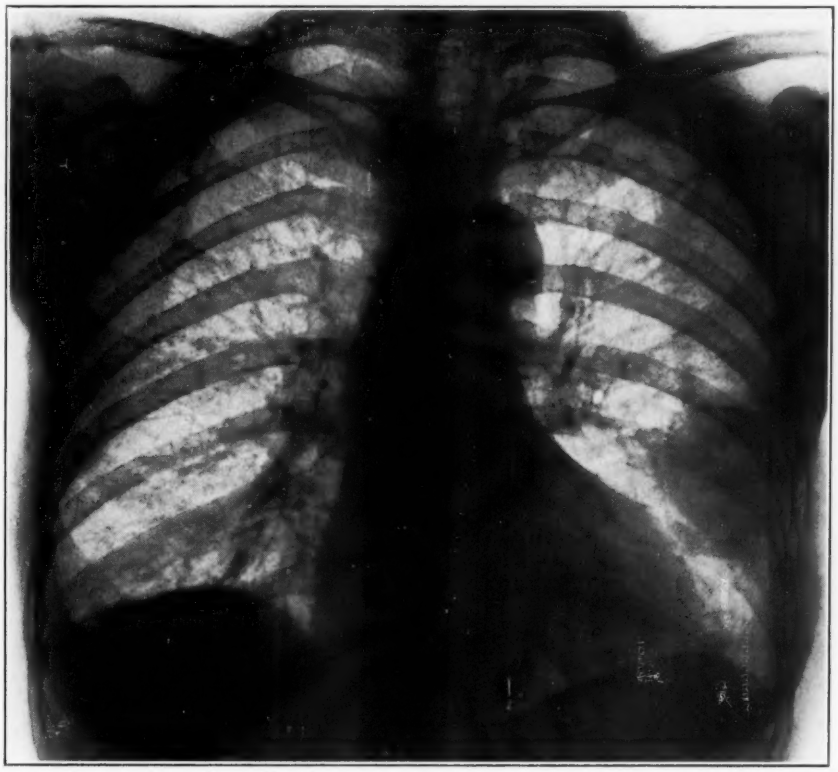

Fig. 10.—(Case 15.) A peripheral circumscribed shadow simulating a pulmonary neoplasm.

COMMENT ON CASES WITHOUT DISTINCTIVE ROENTGENOLOGIC FEATURES

The important pathologic lesions were obscured in the roentgenograms of three cases by pleural effusions. In two of these there was evidence suggesting pulmonary excavation. In two other cases, in which lateral views were not taken, there was no roentgenologic evidence pointing to pyopneumothorax. The roentgenologic appearance in Case 16 was that of primary peripheral pulmonary cancer. The only clue to the possibility of lung abscess was the history of a recent dental operation.

OPERATIVE TREATMENT

In a number of the cases in this series repeated negative exploratory punctures were performed before pus was obtained with resultant delay in operation. Unavoidable in some, such delay would have been avoid-

TABLE I

TABULATION OF CASES

CASE	SYMPTOMS	ROENTGEN FEATURES	PATHOLOGY AT OPERATION	TREATMENT	RESULT
1. No. 400117	5 wk. duration; productive cough, loss 10 lb. in weight, anorexia	Left interlobar effusion	Pneumococcus Type 32 (aerobic); ruptured abscess into left interlobar fissure; infection of right lung and pleura	Aspiration, thoracotomy, rib excision, packing of wound	Death 29 days after operation of infection in right lung (no post mortem)
2. No. 326997	7 wk. duration; respiratory infection, fever, cough, with free interval	Effusion into main right interlobar fissure	*Staphylococcus aureus* and *Staph. albus* (aerobic); perforated pulmonary abscess at under surface right lower lobe with empyema cavity in fissure	Aspiration, stab thoracotomy, subsequent packing of pulmonary cavity for hemorrhage, intercostal drainage for tension pneumothorax	Death because of continued infection in general pleural cavity (no post mortem)
3. No. 388472	3 wk. duration; fever, dyspnea, cough, fetid sputum	Fluid level and air in fissure; smaller loculation in posterior left axilla	Anaerobic (foul) pyopneumothorax of interlobar fissure with perforated pulmonary abscess of inferior surface left upper lobe	Thoracotomy, rib excision, revision of wound	Well in 6 wk.; bronchial fistula healed
4. No. 379743	3 wk. duration; cough, fever, toxemia	Interlobar pyopneumothorax, right	Nonputrid (aerobic) pneumococcus interlobar pyopneumothorax (right) with small perforated abscess of upper portion right lower lobe	Thoracotomy, rib excision, packing	Well in 4½ wk.; bronchial fistula closed
5. No. 316076	3 wk. duration; cough, chest pain, foul expectoration	Two fluid levels in left lower lobe, the larger lying near the fissure; apical infiltration	Anaerobic (foul) perforated abscess upper portion left lower lobe with foul pus in fissure	Thoracotomy, rib excision, subsequent aspiration, stab thoracotomy	Died; post mortem: purulent bronchitis left lower lobe, bronchopneumonia right lower lobe

6. No. 390457	7 days' duration; upper respiratory infection, cough, fever, expectoration; profound toxemia	Two fluid levels in the anterior right chest; one thought to be in the pleura, the other in the lung	Anaerobic (foul) pus in interlobar fissure (no attempt to locate pulmonary focus)	Thoracotomy, rib excision, packing of cavity	Death shortly after operation from the continuation of sepsis
7. No. 384052	10 days' duration; pain in chest, fever	Large anterior loculation, bowing the right short fissure	Anaerobic (foul) pus in posterior portion of long fissure (right); bronchial fistula postoperatively	Aspirations of chest, thoracotomy, rib excision	Well 4½ wk.; bronchial fistula healed
8. No. 397696	6 wk. duration; cough, foul sputum	After operation for putrid abscess, extension of disease along fissure	Anaerobic lung abscess right middle lobe; lung abscess axillary portion right upper lobe with interlobar empyema and old abscess right upper lobe	Thoracotomy, rib excision, revision of wound, subsequent thoracotomy, packing of cavities and fissure	Well after several months; healed bronchial fistulas
9. No. 345222	3 wk. duration; upper respiratory infection, pain in chest, cough, foul sputum	Sharply circumscribed pneumothorax in middle one-third of right lung	Anaerobic pyopneumothorax right interlobar space; perforated abscess upper surface right lower lobe	Thoracotomy, rib excision, packing of wound	Rapid healing
10. No. 399013	10 days' duration; fever, hemoptysis, foul sputum; cavity (nontuberculous) left upper lobe 7 yr.	Large pleural effusion	(1) Anaerobic interlobar abscess with perforated abscess under surface left upper lobe; (2) putrid empyema in free pleural cavity; (3) abscess left lower lobe; (4) anterior parapericardial abscess	(1) Thoracotomy, rib excision, packing of cavity and abscess (left upper lobe); (2) Drainage of empyema; (3) drainage of abscess (left lower lobe); (4) Drainage of parapericardial collection	Slow convalescence; well after several months, fistulas healed
11. No. 378869	10 days' duration; fever, cough, dyspnea	Several areas of translucency in massive pleural effusion	Large pneumococcus (aerobic) empyema at interlobar fissure; ruptured abscess left lower lobe near axilla	Aspiration, thoracotomy, rib excision	Satisfactory; wound healed

TABLE I—CONT'D

CASE	SYMPTOMS	ROENTGEN FEATURES	PATHOLOGY AT OPERATION	TREATMENT	RESULT
12. No. 338310	2 wk. duration; follicular tonsillitis; chest pain, fever, cough, foul sputum	Suggestive fluid level in large right posterolateral effusion	Anaerobic (foul) pus in long fissure; small abscess inferior surface right upper lobe	Aspiration, thoracotomy, rib excision, packing of fissure	Satisfactory; wound and fistula healed
13. No. 403508	10 days' duration; fever, chest pain, cough, chills; foul expectoration on one occasion only	Loculation of fluid in midst of supposed lobar pneumonia	Anaerobic (foul) pus in interlobar fissure; neither pulmonary abscess nor bronchial fistula demonstrated	Aspiration, thoracotomy, rib excision, packing of wound	Uneventful recovery
14. No. 314641	3½ wk. collapse, fever, cough, purulent sputum	Posterolateral pleural exudate, with suspicion of several cavities above this region	Interlobar collection of odorless (aerobic) pus between right upper lobe and right lower lobe with a ragged perforated abscess right upper lobe	Aspiration, thoracotomy with rib excision and packing of wound	Good; discharged with bronchial fistula which subsequently healed
15. No. 310124	2½ wk. duration; post-tonsillectomy, fever, cough, no sputum	Partial collapse of right lung with suggestion of excavation of upper lobe; also periapical empyema	Anaerobic (foul) pus in fissure between right upper lobe and right lower lobe; perforated abscess at under surface right upper lobe; infection of general pleural cavity	Thoracotomy, rib excision, tube and packing inserted; several subsequent thoracotomies	Good; all wounds healed
16. No. 375784	4½ wk. duration; pain in chest, cough, fever	Sharply circumscribed lesion in left lung, suggesting a peripheral type of malignant pulmonary neoplasm	Anaerobic (foul) bilocular interlobar collection of pus with small abscess at under surface left upper lobe	Aspiration, thoracotomy, and rib excision; packing of cavity	Well; early closure of bronchial fistula

able in other cases in this series if more consideration had been given to the interpretation of films and greater efforts made at precise localization of lesions.

Pus or purulent fluid withdrawn by aspiration need not necessarily be derived from the interlobar focus, for an adjacent, so-called, sympathetic effusion may be the source. This proved to be true in two of our cases in which pus different from that in the interlobar space was encountered by the aspirating needle inserted into the general pleural cavity near the involved interlobar fissure.

Fig. 11.—A case of pulmonary abscess without perforation into the pleura. The roentgenogram, however, is characteristic of an interlobar effusion within the long fissure.

The chief danger of operation consists of the possibility of entry into the free pleural cavity in order to obtain access to the interlobar collection of pus. Adhesions to the parietes exist in most cases, but they are apt to occupy narrow bandlike zones. With accurate roentgen localization, such a narrow band not only can be found but also can be followed into the interlobar collection of pus without entrance into the free pleural cavity. The most painstaking attention must be given to any

opening of the free pleural space whether intentional or inadvertent, for the crux of the operation is the avoidance of a generalized pleural infection. If the free pleural cavity has been entered, fine surgical judgment is involved in the decision to proceed with a one-stage operation or to perform a two-stage operation. The one-stage operation was followed by death in one case in our series and by a fulminating generalized pleural infection in another.

Although simple drainage of the interlobar abscess, whether performed in a one- or a two-stage procedure, may suffice, it may also prove to be inadequate for cure. The reason lies in the pathology of the lesion. The underlying abscess of the lung may be small or may be of substantial proportions, the perforation may be small or large, the interlobar collection of pus may be single or multilocular. Therefore, the result of operation remains in doubt if the underlying cause is not disclosed. Accordingly, the operative procedure should consist, in our opinion, of a wide opening of the interlobar collection of pus, the visualization of the perforated pulmonary focus whenever possible, and the enlargement of the opening of the pulmonary abscess when it appears to be small or inadequate. At the end of operation the pulmonary cavity is packed with gauze if it has been unroofed, and the space which had been occupied by the interlobar abscess is also packed.

The ideal surgical approach to the interlobar collection of pus is by means of the separation of the two enclosing lobes. However, entry to the interlobar abscess may not be possible without traversing a thin shell of lung. There are instances in which one may not be certain, even at the end of operation, as to whether the collection of pus was an unperforated pulmonary abscess lying on a fissure or a pulmonary abscess which has perforated into a fissure.

Interlobar perforated abscess of the lung obviously is a serious lesion, but its mortality in the present series of cases is ascribable, at least in part, to errors in precise localization and in operative treatment. Concerning the latter, avoidance of pleural infection and adequate drainage of the suppurative focus or foci should yield excellent results if operation is not inordinately delayed.

SUMMARY

In a small series of cases so-called interlobar empyema proved to be an interlobar collection of pus due to the rupture of a pulmonary abscess facing an interlobar surface. The causative abscess is more often putrid (anaerobic) than aerobic. The lesion is rare and often is erroneously diagnosed. There are no clinical criteria for its recognition. The roentgenologic criteria, whereby a correct diagnosis can be made, are: an interlobar collection of fluid or of fluid and air; a fluid level on or near a fissure; an alteration in the shape of a fissure; progression of disease along a fissure. These distinctive features occurred in more than one-half the cases, but were obscured by overlying pleuritis in the remainder.

The basis for correct surgical treatment is the roentgenologic recognition of the lesion. Many exploratory punctures may be performed before pus is encountered. The interlobar situation of the abscess often is not realized until the time of operation. If the free pleural cavity is traversed at operation, a two-stage procedure should be employed unless the general pleural cavity can be sealed off adequately. The interlobar collection of pus should be opened fully and drainage placed to the site of rupture of the pulmonary abscess. The opening of the abscess of the lung should be enlarged when the perforation is inadequate for drainage. The mortality of interlobar ruptured abscess of the lung is not referable apparently to the nature of the lesion but to prolonged delay in diagnosis, erroneous roentgenologic interpretation, and, above all, operative treatment which does not take into account the causative pulmonary abscess or which results in infection of the free pleural space.

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THE USE OF AUTOGENOUS RIB CARTILAGE GRAFTS TO REPAIR SURFACE DEFECTS IN DOG JOINTS

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THERE is still argument as to how fully and in what manner loss of cartilage from a joint surface repairs itself. Clinically there is a general belief that such a loss either remains unhealed or fills in with fibrous tissue. This belief may be erroneous because most cartilaginous articular defects observed at the operating table are due to disease and in such instances the cartilage surrounding the denuded area is abnormal. Such diseased cartilage probably cannot be expected to have normal powers of regeneration.

Until about 1850 there was complete agreement that articular cartilage had no power whatever to heal itself. The first evidence to the contrary was submitted by Redfern in 1851. He made defects in the articular cartilage of a dog's joint and observed that after a sufficient length of time these healed perfectly by fibrous tissue. This fibrous tissue was composed of both yellow and white fibers.

From 1850 to the present time, there has been an increasing amount of experimental evidence accumulating on the subject. For those interested, there is a good review of the work done during this period in Shands' article. Suffice it to say that some investigators still believe that cartilage does not heal when wounded. Others have observed that, if the defect is down to subchondral bone, then the area heals by fibrous tissue; while still others believe that a wound purely in cartilage heals first by fibrous tissue which later actually may change into a type of fibrocartilage. The evidence, then, during this period was somewhat contradictory, but there was a growing belief based on animal experiments that cartilage healed itself even if this healing was perhaps rather feeble and by fibrous tissue.

Recently, there has been some further experimental evidence submitted. In 1931, Shands made rather extensive studies of the regeneration of hyaline cartilage in joints of dogs. Three classes of surgical defects were studied: deep, superficial, and direct trauma. He concluded that the best evidences of regeneration are found about twelve weeks after injury, that regeneration does take place in superficial cartilaginous wounds, but the greatest amount of regeneration is observed if the injury involves subchondral bone. He concluded that cartilage heals by an orderly process of connective tissue replacement

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which then becomes fibrocartilage and finally hyaline cartilage. He noticed that articular cartilage occasionally responds to direct trauma with proliferation of nests of new cartilage cells.

In the same year, 1931, Key, using the knee joints of rabbits, produced surgical defects in the hyaline cartilage of the patellar groove. He then studied these joints for evidences of healing at intervals of eight days to seven months. In these experiments a great variation in healing of similar defects was noted. In some instances the bone remained bare; in others the defect was covered by loose connective tissue with the wound actually deeper than originally, due to erosion of the underlying bone. In some joints there was repair by cartilage which Key thought might be due to metaplasia of osteoid tissue into cartilage.

In 1932, Bennett and Bauer, of Harvard, using adult dogs, reported that in seven of nine defects made entirely in the articular cartilage some form of repair occurred. In no instance was this repair complete and in a majority only a small portion of the wound was healed. In wounds made through the articular cartilage and extending into subchondral bone, healing by fibrous tissue took place. This gradually changed into fibrocartilage and eventually into an imperfect form of hyaline cartilage.

In 1935, these authors repeated this work, using puppies instead of adult dogs as the experimental animals and found no difference in the healing power of young as compared to older dogs. They did note that in a wound made only in the cartilage of the knee joint repair took place most satisfactorily in "protected crevices."

From the above it can be seen that there has gradually accumulated experimental evidence that cartilage heals itself when wounded. This healing, however, does not always take place and at best is rather imperfect. Because of these facts, it occurred to us that it might be possible to heal such defects more perfectly by actually grafting a piece of autogenous costal cartilage into them, and with this in mind we undertook the following experiment.

METHOD OF EXPERIMENT

Young dogs, 6 months to 1 year old, were used as in older dogs there is apt to be considerable central ossification of the costal cartilages. The operations were performed under ether anesthesia and aseptic technique. Ten dogs were used in these experiments. In each instance the costal cartilages on the right side were exposed. Through an oblique incision over the protruding costal margin, a section of rib cartilage about 8 cm. long was resected and the perichondrium completely removed. Two sections of this costal cartilage, approximately 2 cm. long, were cut in rectangular shape. Each knee joint of the animal was opened through a median parapatellar incision, the patella gently retracted laterally to expose the superior patellar groove between the nonweight-bearing

superior extension of the patellar condyles, and a rectangle of articular cartilage, corresponding in shape to the previously fashioned pieces of costal cartilage, removed. A thin portion of subchondral bone was included with this. The rectangle of rib cartilage was inlaid in this rectangular slot so that it fit snugly and its surface was flush with the contiguous articular surface. In some instances the graft was stable without any fixation; in others it was necessary to hold the transplant in place with a few fine sutures of plain catgut or a couple of milliner's needle points used as tacks. The patella was dropped back in place and the incision was repaired in layers with silk.

In the last three dogs operated upon, the experiment was varied in that a section of hyaline cartilage about 2 cm. long was removed across the complete joint surface and resurfaced with three strips of costal cartilage placed side by side.

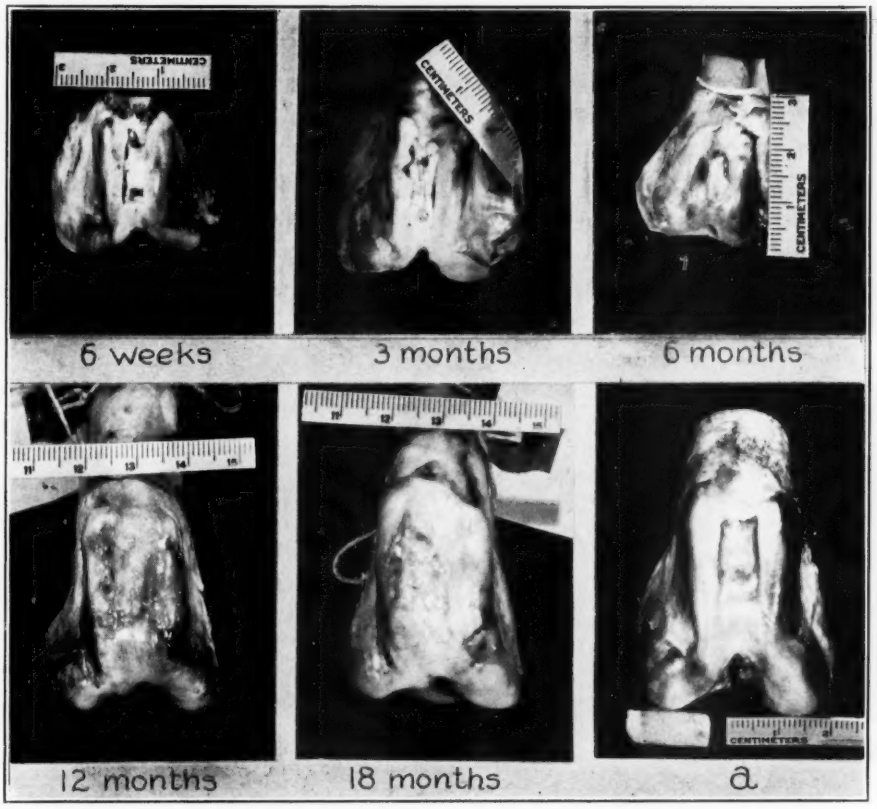
Following operation, no attempt was made to immobilize the joint. For the first few postoperative days the dogs would protect the joints by refusing to walk, but in a short time they began to get about in normal fashion.

In all, ten dogs were operated upon, making a total of twenty intra-articular grafts available for study. The dogs were sacrificed under ether anesthesia at such intervals that joints were available for study from ten days to eighteen months following introduction of the graft.

After sacrificing the animals, the joints were removed intact by sawing through the femur and tibia above and below the extent of the synovial reflections. All soft tissues were removed. The joints were opened and examined and photographs made of the interiors. Following this, the specimens were fixed in Zenker's solution plus formalin. They were then washed, decalcified with nitric and lactic acid, washed, neutralized with sodium sulfate, washed, and embedded in paraffin by the chloroform method. Microscopic sections were cut and stained with hematoxylin and eosin. Serial sections were made at right angles to the graft so that the full extent of the junction of the cartilage graft with the contiguous articular cartilage and the bone on which it was placed could be studied.

GROSS EXAMINATION OF THE JOINTS

Twenty joints were thus made available for study. Of these, one showed extensive fibrous adhesions between the joint capsule and articular surfaces which rendered study unprofitable. In a second the piece of transplanted rib cartilage was free as a joint mouse. In this instance the defect made for reception of the graft was still plainly visible (one year after operation), but the surface was covered with a glistening, smooth tissue resembling cartilage. The free transplant was firm; its ends had rounded off, but it had not decreased appreciably in size. The remaining eighteen joints were carefully examined for evidence of healing between the transplant and the articular cartilage and for signs of disintegration or change in character of the graft.



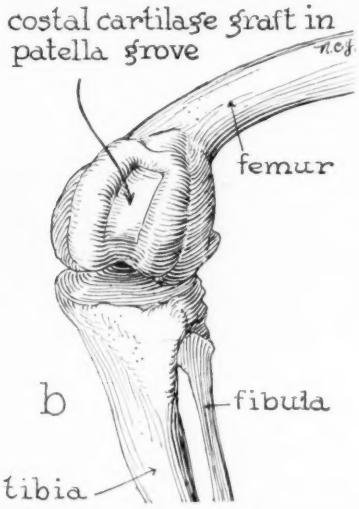


Fig. 1.—Gross photographs of dog knee joints, showing the appearance of costal cartilage grafts at intervals of six weeks to one and one-half years following transplantation. *a*, A joint, one year after transplantation, in which the costal cartilage graft was loose as a joint mouse; *b*, diagram of location of transplant in patellar groove.

The earliest a joint was examined following operation was ten days. In this specimen the transplant was loosely adherent to the defect. The small space between graft and defect margins was filled with a soft pale red tissue which looked like granulations.

At six weeks the graft was firmly attached. In areas where the edge of the transplant was originally in good approximation with the articular cartilage there was a smooth union. In places where the original fit of the graft to the defect was not quite so accurate, a defect still existed. There seemed to be no change in the character of the transplant. It was still firm; there were no surface erosions or fibrillations, and its surface was smooth, glistening, and the color of hyaline cartilage.

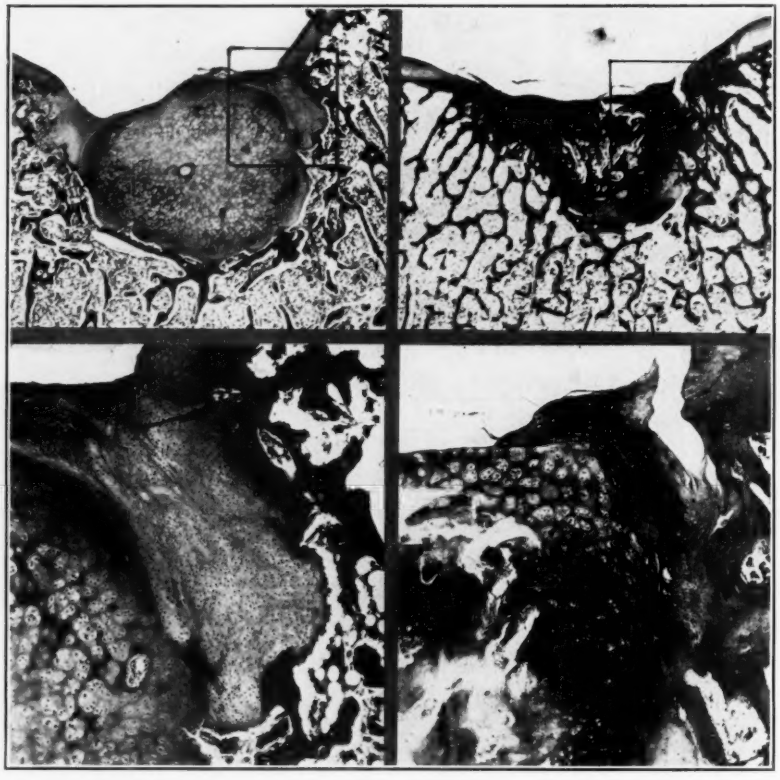


Fig. 2.—*A*, A photograph (×15) of a six-week-old transplant. It is well connected with the articular cartilage by fibrous tissue; *B*, an area (indicated by lines drawn on *A*) from this same microscopic section (×60); *C* and *D*, photomicrographs (×15 and ×60) from a three-month transplant. The central ossification was present in the rib cartilage when transplanted.

The joints of the three-month animals did not appear much different from those examined at six weeks. The graft was firmly attached and still normal in general character. In some areas around the periphery there was a smooth firm union with articular cartilage. The main differences noted from those grafts examined at an earlier date were that there were some small superficial erosions on the surface of the

transplant, and, in places where the graft had not been snugly placed, the adjacent articular cartilage showed irregular erosions.

The joints in which the transplant had been in place for six months showed more evidence of healing than any of those previously examined. Although there was in places a marginal defect which had not leveled out, in most areas the surfaces of the transplant and the surrounding joint cartilage were flush. The line of union of the two was still plainly visible but smooth. The surface of the transplant was smooth and hyaline but had a pink cast as though it might be becoming vascularized.

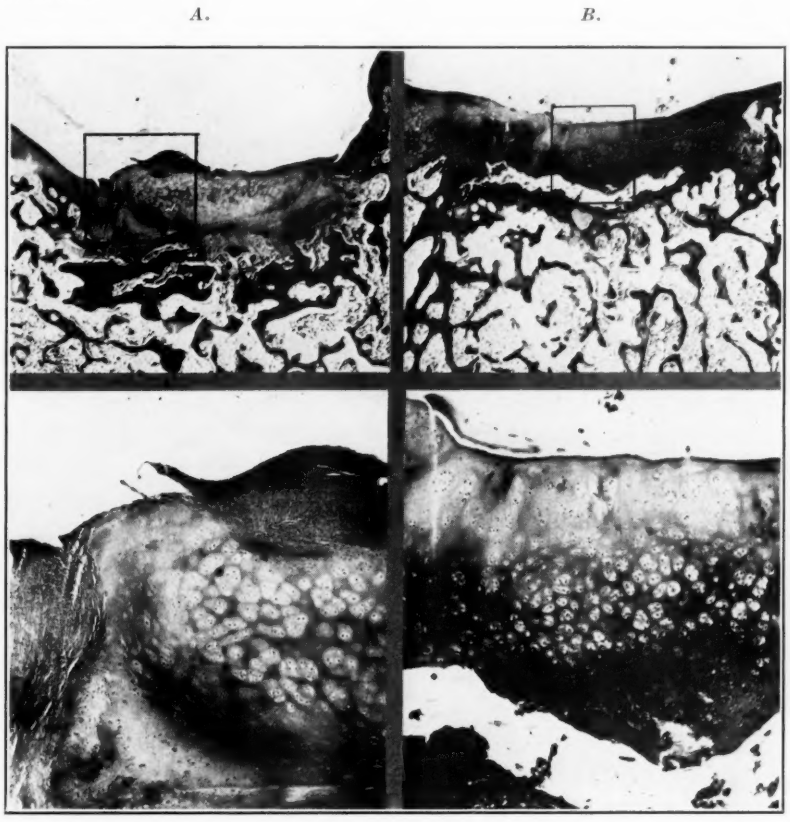


Fig. 3.—*A* and *B*, Photomicrographs (×15) of costal cartilage transplants six months and one year after placement in patellar groove of dog's knee joint; *C* and *D*, the same (×60). The separation of the graft from the bone in the one-year-old specimen is an artifact due to sectioning. Both of these specimens show the cartilaginous graft living and firmly attached.

The specimens examined at twelve and eighteen months were joints in which not one single inlay graft had been done, but, as mentioned above, in which a defect had been made completely across the articular surface down to bone and then three strips of rib cartilage laid side by side to resurface the defect. Conclusions drawn from these specimens may be open to criticism since they were not carried out in exactly the same manner as the preceding experiments. It is conceivable that pan-

nus growing in from the edges laterally may have contributed to appearance of the transplants. At any rate, at the end of a year there were very marked changes in the gross appearance of the transplants. The grafted area was a smooth, glistening pink with only faint markings indicating where the strips of cartilage had been placed.

The specimens examined eighteen months after transplantation showed further lack of definition of the strips of rib cartilage. In these the area in question was covered with an irregular, thin, pink-white material which was somewhat macerated in appearance. Small irregular areas of the original grafts were present but looked as though they might soon be absorbed or cast off.

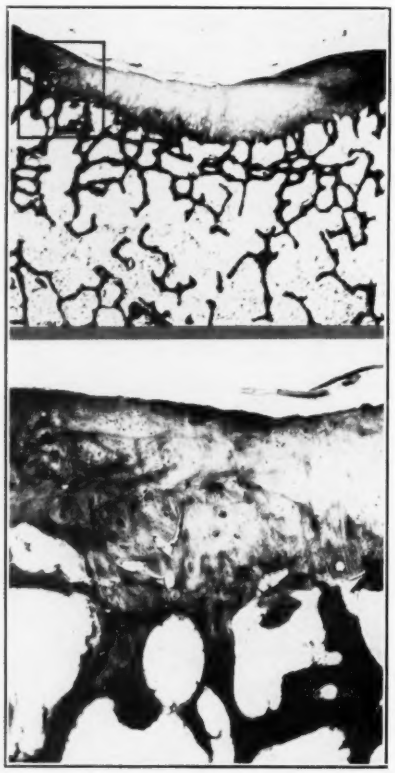


Fig. 4.—*A*, Photomicrograph (×15) and *B* photomicrograph (×60) of a transplant at eighteen months. The cartilage is almost replaced by osteoid appearing tissue.

MICROSCOPIC EXAMINATION OF THE JOINTS

Histologic sections were made from similar areas in each joint. These were made in serial fashion so that cross sections of the entire articular surface with the graft in the central portion were obtained. All sections were decalcified and stained with hematoxylin and eosin.

Microscopic sections made of the joints in which the transplant had been in place ten days showed an early healing process going on around the graft. The space between the cartilage of the graft and the sub-

chondral bone was filled with leucocytes and young connective tissue. On the surface, where articular cartilage was adjacent to transplanted cartilage, strands of connective tissue were seen bridging the gap. The cartilage cells throughout the transplant appeared normal. The adjacent articular cartilage was normal.

The transplants of six weeks' duration showed microscopic evidence of being firmly united to both the subchondral bone and the articular cartilage. In places this union to bone was so perfect that no microscopic tissue was present between bone and cartilage, while in others a small layer of fibrous tissue bound the two together. The union between the articular cartilage and joint cartilage was by fibrous tissue and this extended across the surface of the transplant as well. In none of this cementing fibrous tissue could any cartilage cells be found. The cartilage cells of the graft were well formed and normal appearing. This obtained on all sides of the transplant, on inner as well as lateral and external surfaces.

The specimen removed and examined at three months showed the graft to be firmly united to all adjacent tissue by adult fibrous tissue. The articular surface of the transplant for the most part was covered by this connective tissue. Where the graft rested on subchondral bone, there was a firm union by fibrous tissue. The central portion of this graft was ossified when originally transplanted. The cartilage on its periphery still appeared normal and the cells were viable.

At six months the graft microscopically was firmly grown in place and the cartilage normal and viable in appearance. There was no evidence of any cartilaginous growth in the fibrous tissue connecting articular cartilage with the rib transplant. However, cells within the graft in places seemed to be multiplying.

The specimen examined at one year was, as we have mentioned above, somewhat different in that strips of rib cartilage were laid side by side on the denuded subchondral bone. These strips, grossly, were still visible but not clearly defined. On microscopic examination this was found to be due to the strips actually having coalesced. In places on the surface the junction of the strips could be made out. In the depths of the transplants, however, there was one continuous sheet of hyaline cartilage. The strips had not healed together by fibrous tissue connections but by actual hyaline cartilage. This is of interest because in none of our specimens was articular cartilage healed to rib cartilage by other than connective tissue, but these strips of costal cartilage did heal by cartilaginous union.

The longest time interval in these experiments was eighteen months. These sections showed a practically complete absence of cartilage on the articular surface. There was instead a covering of the articular surface by a layer of tissue of approximately the same thickness as the remaining cartilage seen in the sections of twelve months' duration.

This tissue was composed of cells smaller than those of cartilage, without the characteristic clear surrounding zones and more compactly arranged. They were embedded in a hyaline-like matrix which showed radial striations which stained a little darker pink than most of the ground work. This tissue, we believe, represented an almost complete replacement of the rib cartilage grafts by osteoid tissue.

DISCUSSION

It is a well-known clinical and experimental fact that cartilage is one of the most satisfactorily transplanted tissues. Autogenous rib cartilage can be transferred under skin, to subcutaneous tissue, to muscle, in contact with bone, in fact, to almost any location, and will maintain its metabolism with little or no loss in size or microscopic change.

Loeb's experiments show that of the cartilage grafts from various sources autografts are tolerated with less reaction and with less eventual loss of substance than are either iso- or heterografts, when transplanted subcutaneously.

Davis found that cartilage grafts are preserved in toto when transplanted subcutaneously in dogs with one end of the graft in contact with bone, while similar experiments with bone grafts show that they are gradually completely absorbed.

Fisher experimentally showed that bits of cartilage chiseled off an articular surface and left free in a joint almost immediately attach themselves to the synovial membrane; that a connective tissue sheath forms around them; and that this sheath derived from the synovium has the remarkable property of laying down new cartilage upon the surface of the original free morsel of cartilage.

Harbin, using dogs, placed small bits of articular cartilage from one knee joint in collodion sacs and introduced these into the other knee joint. A considerable number of these sacs ruptured, but, in three sacs where the cartilage remained inclosed up to thirty-two days, he found that the bit of articular cartilage showed microscopic evidence of being alive and from this he concluded that articular cartilage will survive nourished only by the diffusible elements of the synovial fluid.

We believe that these experiments are in agreement in the main with the generally accepted view that autogenous cartilage grafts live in almost any location. The fact that our oldest specimens (eighteen months) showed replacement of the graft by osteoid tissue is somewhat against this. However, in studying the various sections it was evident that technique enters into the final result quite considerably. If the graft had been fitted snugly into the defect, a firm healing took place; if there was a considerable space between edge of defect and edge of graft, osteoid tissue developed. As all other specimens from ten days to a year showed the grafts to remain viable, it would seem that this

is the most reasonable explanation of osteoid replacement in these eighteen-month-old specimens.

It is of considerable interest that in no section did we observe cartilaginous healing between articular cartilage and the rib cartilage graft, this union always being fibrous. However, when rib cartilage grafts were placed in contiguity on the denuded joint surface, they healed into one sheet of hyaline cartilage. This may indicate that although rib cartilage and articular cartilage are both hyaline and appear identical microscopically, they may be different biologically.

SUMMARY

1. Rib cartilage grafts have been transplanted into surgical defects in the articular surfaces of knee joints in young dogs. These defects were made down to subchondral bone in the superior patellar groove between the femoral condyles which is a nonweight-bearing area.

2. The grafts were studied at intervals of from ten days to eighteen months following transplantations.

3. Rib cartilage grafts placed in parallel on the denuded joint surface healed together by cartilaginous union; whereas, articular cartilage and rib cartilage always united by fibrous tissues.

4. Gross and microscopic studies show that these grafts healed in place by fibrous tissue connections and remained viable for as long as a year. At eighteen months there was partial replacement of the graft by osteoid tissue which could probably be explained on a technical basis.

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THE MANAGEMENT OF OLD CONTRACTURES OF THE HAND RESULTING FROM THIRD DEGREE BURNS

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CONTRACTURES of the hand and digits as a result of burns are common, and these deformities often can be corrected, with subsequent improvement in the function of the hand by suitable operative measures. Each patient presents an individual problem and it is important to estimate the depth of the scar, its attachment to, and possible distortion of, the deeper structures of the hand, before deciding on the method of repair to be used in the particular case. Even though the deformity may have been present for a decade or more and during the growth period of the individual, much can be done to improve the usefulness and appearance of the member. Supplementary physiotherapy directed toward early restoration of function is an invaluable adjunct to surgical treatment. Davis, Blair, Brown, and others have enumerated the principles to be followed in handling these cases and have obtained excellent results in their treatment.

The patients with contractures of the hand presented herein fall readily into three groups. In the first are those individuals having cicatrices on the palmar surfaces of the digits, which in some instances extend down on the palm itself and cause weblike flexion contractures of the fingers. These webs frequently may be released by the interposition of flaps formed by incisions made at an angle to an incision along the leading edge of and splitting the contracture itself, a procedure advocated by Morestin in 1914[1] and recently reviewed by Davis and Kitlowski.[2, 3]

The scars present in the second group of patients are broad but are unattached to the deeper structures of the hand and are best treated by excision of the cicatrix with the underlying fascia, leaving a protective layer of fat over the nerves, muscles, and tendons beneath. When the palm or the palmar surface of the finger is the site of the contracture, the defect created by excision of the constricting scar may be covered with a full thickness or Wolfe-Krause graft. A thick split graft may be used if the dorsum of the hand or the finger is to be covered with skin.

A representative contracture of the third type is caused by a scar which extends from the skin to the muscles, ligaments, tendons, or joints of the hand. This fibrous tissue should be stretched as much as possible by intensive physiotherapy before operation. A full range of motion of the hand and fingers may follow excision of the cicatrix in many of these cases, but unless an adequate fat pad is interposed

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Fig. 1.—(History No. 87394, W. F., 7 years of age.) *1* and *2*, contractures of the palmar aspect of the thumb and small finger of two and one-half years' duration, released by the interposition of Z-shaped flaps; *3* and *4*, result two years after operation. Insert shows method of raising the angle flaps along the palmar webs.

between the skin and the deeper structures the constricting scar in time will reform and the result will be unsatisfactory. Elastic traction and other physiotherapeutic measures are of great assistance in obtaining early return of function after operation.

The first group of cases mentioned above is exemplified by the patients shown in Figs. 1, 2, and 3. In these cases there were web contractures on the palmar aspects of the fingers which were released by the interposition of angle flaps. The patient shown in Fig. 3 deserves especial comment. The deformity of the index and middle

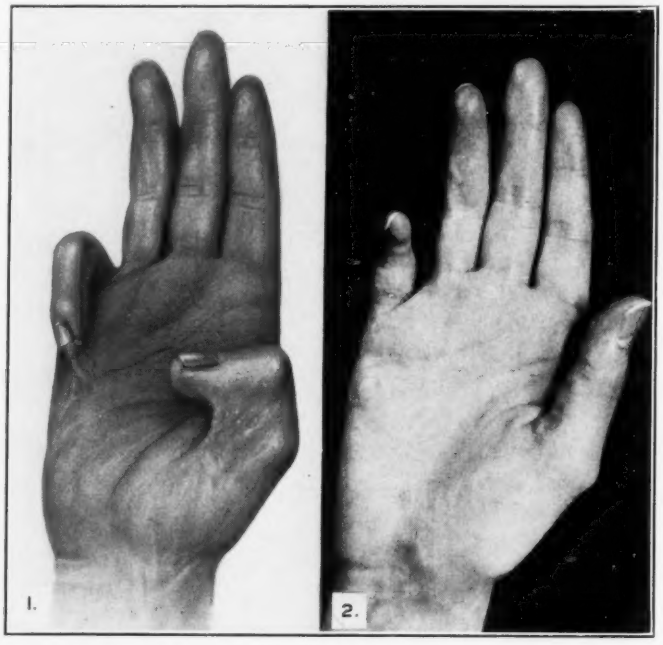

Fig. 2.—(History No. 20394, W. F., 23 years of age.) *1*, Contractures of the palmar aspect of the thumb and small finger of twenty-one years' duration released by the interposition of Z-shaped flaps. The end result seven years after operation is shown in 2. Although slight flexion of the small finger is present, the functional result is excellent.

fingers had been present for thirteen years; nevertheless, full extension was obtained by the method described above. However, the scars on the palmar aspect of the index finger were painful and, in order to relieve this discomfort and to provide a better fat pad for this area, a tube flap was later transplanted to the palmar surface of this finger.

Examples of the second group of broad contracted scars are represented by the patients' hands shown in Figs. 4 and 5. Although the contracture shown in Fig. 4 was of nine years' duration and that in Fig. 5 had been present for thirteen years, excision of the scars with the underlying palmar fascia allowed the palms to return to their normal size. In both cases the scars extended down to the palmar fascia which was completely removed, leaving a pad of fat overlying the deeper structures of the palm, upon which the full thickness grafts

took with an excellent functional result. The technique followed in correcting these contractures is shown in Fig. 6.

The cicatrix on the dorsum of the hand shown in Fig. 7 was corrected by the use of a full thickness graft. Blair and Brown[4] have

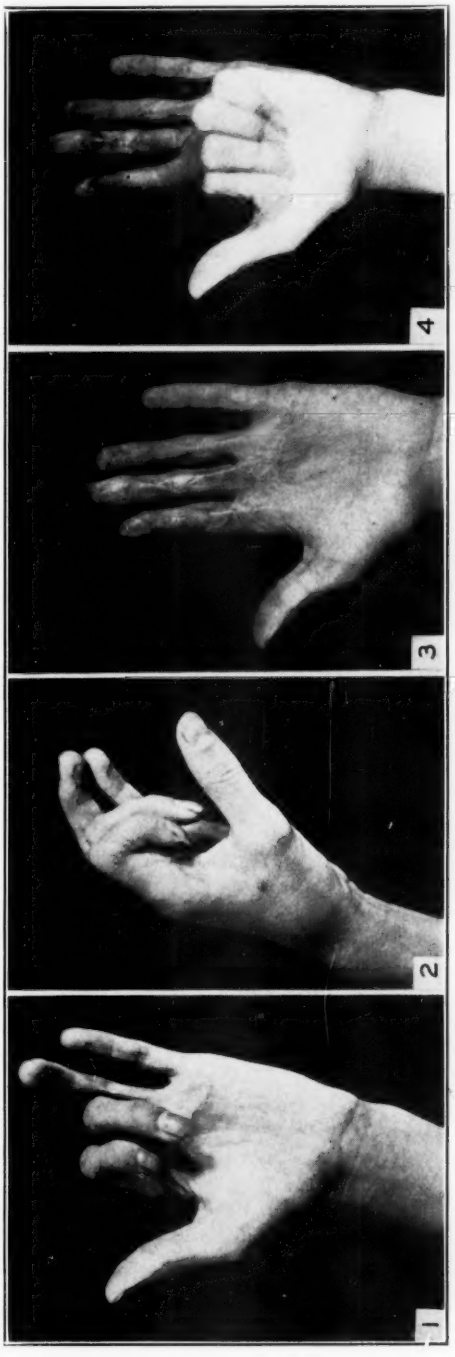

Fig. 3.—(History No. 91984, W. F., 14 years of age.) The flexion contractures of thirteen years' duration shown in *1* and *2* were released by the interposition of Z-shaped flaps with the result seen in *3*. The palmar scars on the index finger were painful and it was necessary to transplant skin and subcutaneous fat by means of an abdominal tube flap to obtain the satisfactory palmar surface shown in *4*.

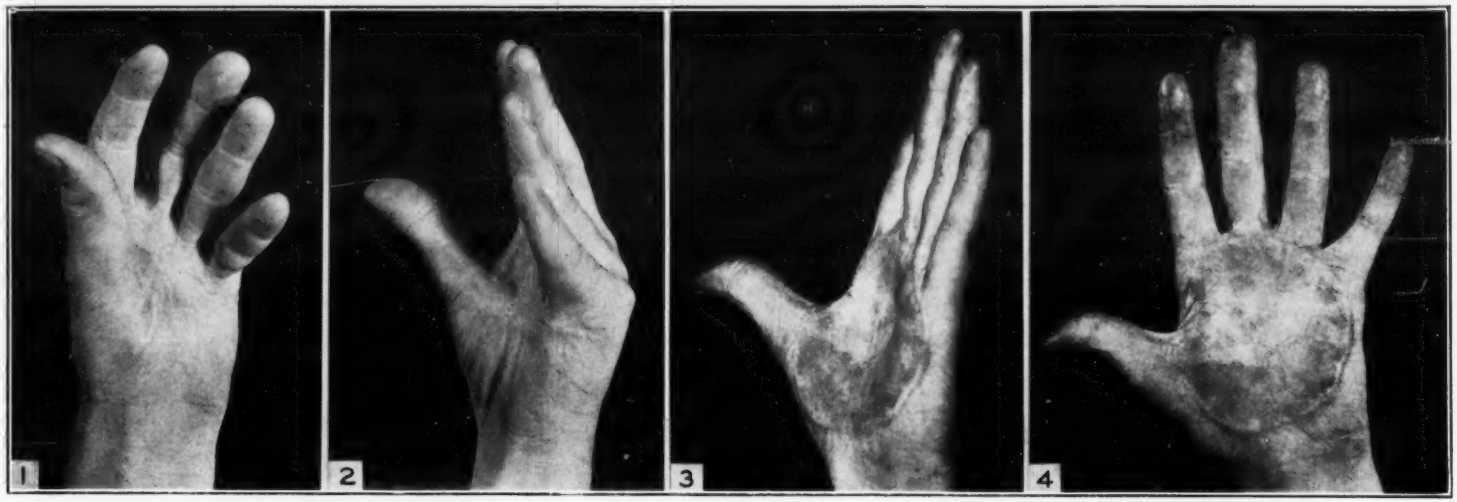

Fig. 4.—(History No. 2240, W. M., 11 years of age.) The palmar scar shown in *1* and *2* had been present for nine years. Complete excision of the cicatrix allowed extension of the palm and fingers. A full thickness graft transplanted to cover the raw area gave an excellent functional result (*3* and *4*). It was necessary for the patient to wear a splint at night for six months to maintain full extension.

shown that durable skin can be obtained by using a thick split graft in such a situation. The result following the application of the latter type of graft to the dorsum of the hand after débridement of a recent burn is shown in Fig. 8.

Contractures of the third group listed above are shown in Figs. 9, 10, and 11. At times the puckering of the scar, the limitation of motion present, and the duration of the contractures will produce a definite impression that the deeper structures are adherent to the skin

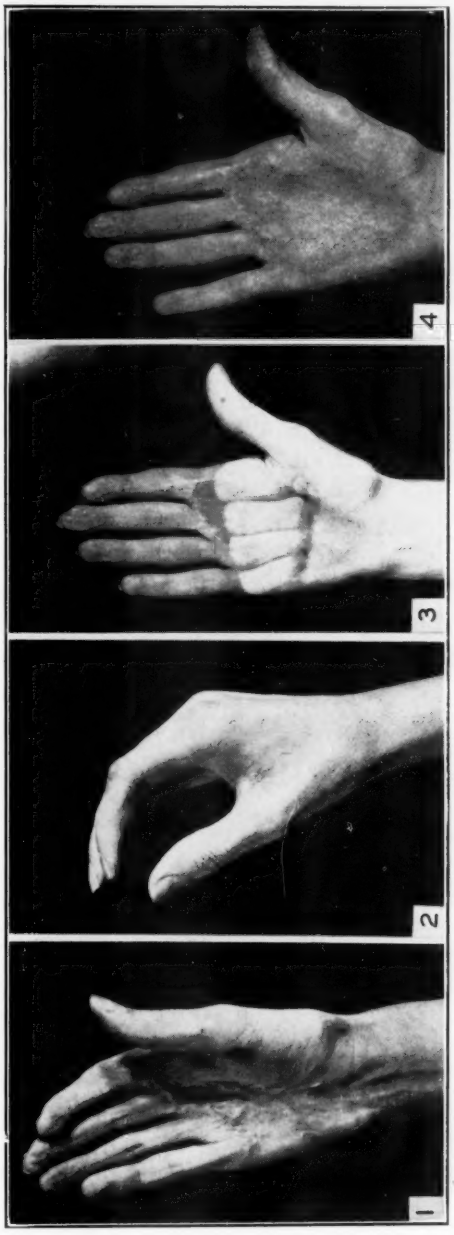

Fig. 5.—(History No. 91984, W. F., 14 years of age.) The contracture of the palm shown in *1* and *2* had been present for thirteen years. Complete extension of the palm and fingers was obtained by excision of the scar and reconstruction of the palm by a full thickness graft (*3* and *4*).

cicatrix. When these findings are present, preparation can be made to place the hand beneath an abdominal flap of skin and subcutaneous fat[5] or to raise a tube flap if this is thought best. At other times, however, the operator may plan to cover the defect left by excision of a palmar contracture with a full thickness graft, but at operation may find the scar deeper than first estimated and the flexor tendons and the carpal ligament exposed after the removal of the cicatrix.

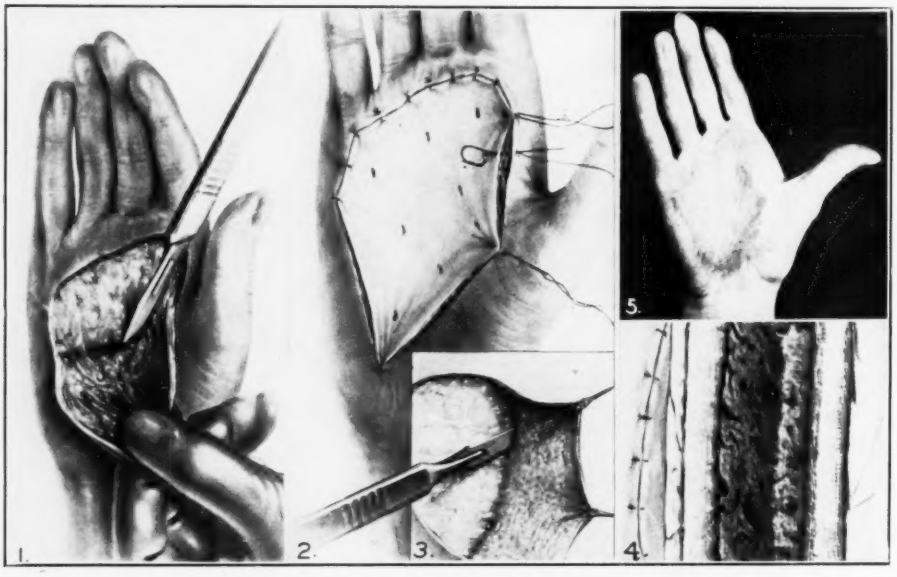

Fig. 6.—Operative technique used in correction of a palmar contracture. *1*, Excision of the palmar scar. The dissection is carried downward to include the palmar fascia which is removed, leaving a layer of areolar tissue and fat over the digital nerves, palmar vessels, and flexor tendons. *2*, The full thickness graft which is taken from the abdominal wall shown in *3* is perforated to allow escape of any serum or blood which might collect beneath it and is carefully sutured into the palmar defect. *4*, A cross section of the dressing shows silver foil next to the palm, covered in turn by xeroform gauze, a marine sponge, dry gauze, and an elastic bandage. The extremity is still further immobilized by splinting the hand and forearm. The end result of such a procedure appears in *5*.

Fig. 7.—(History No. A-7153, W. F., 5 years of age.) *1*, Scarring and contracture of the dorsum of the hand of ten months' duration. *2* and *3*, Result following the transplantation of a full thickness graft to the dorsum of the hand after excision of the scar and release of the contracture.

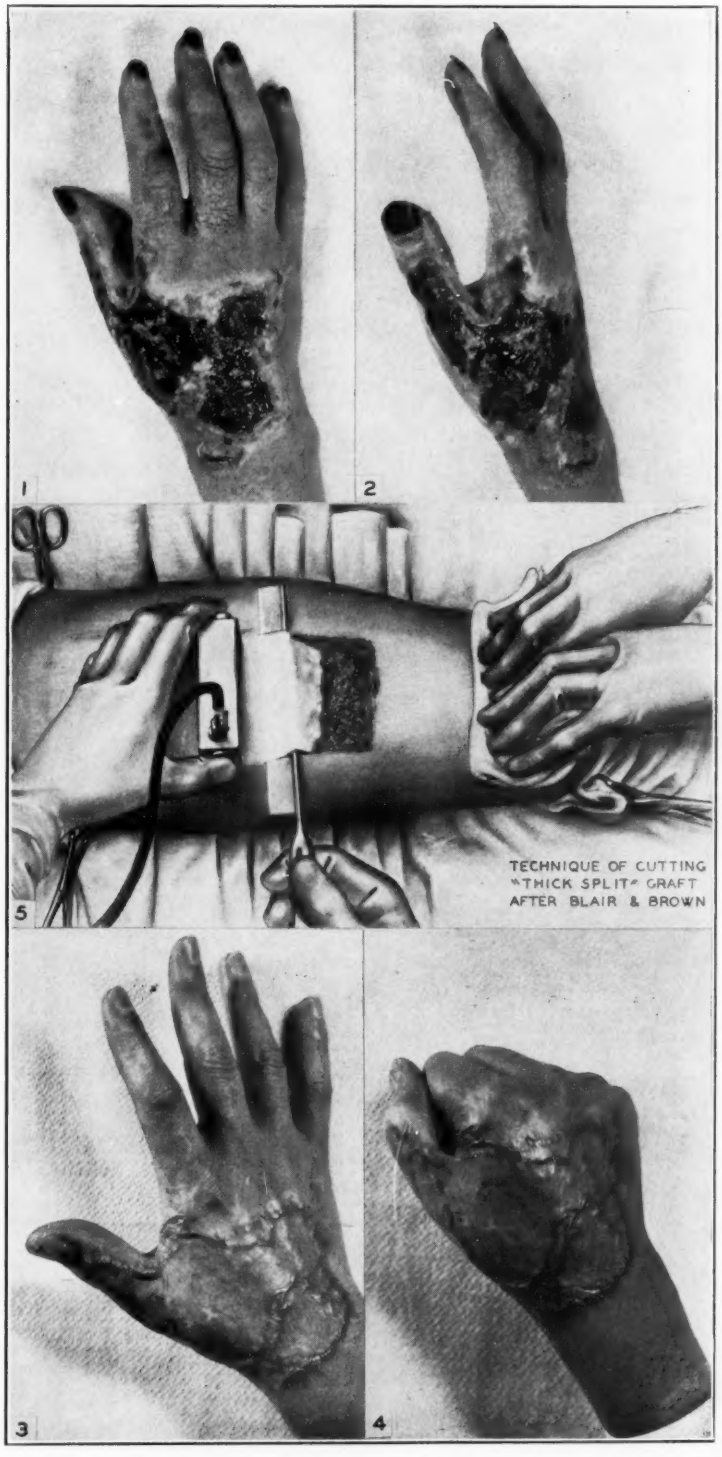

Fig. 8.—(History No. 92578, W. F., 34 years of age.) *1* and *2*, Recent third degree burn of the dorsum of the hand and the thumb from contact with boiling grease. The raw area was covered with a thick split graft from the thigh with the result shown in *3* and *4*, taken five months after the injury was received. The method of cutting a thick split graft after the technique of Blair and Brown is shown in *5*.

A situation of this kind was encountered at operation on the patient's hand shown in Fig. 9. In order to provide the necessary palmar skin and to cover the flexor tendons and the transverse carpal ligament with fat, the defect was filled with a pedicle flap raised from the abdominal wall. The area from which the flap had been raised was covered with a Thiersch graft at the same time. By this means the

Fig. 9.—(History No. A-12317. W. F., 21 years of age.) The contracture of the left hand and wrist shown in *1* had been present for nineteen years. After excision of the scar and re case of the cicatrix, there was insufficient fat and areolar tissue covering the flexor tendons and volar carpal ligament to provi le a satisfactory bed for a full thickness graft. The palmar defect was covered by a pedicle flap from the abdominal wall shown in *2*, and the area from which the flap was raised was covered with a Thiersch graft at the same sitting. The result six months after operation is shown in *3*.

cushion of fat necessary to maintain normal tendon function was obtained and a deformity which had been present for nineteen years was effectively corrected.

A pedicle or tube flap with its subcutaneous fat may prove the only means of releasing a contracture which other measures have failed to relieve. An illustration of this course of events was seen in the treatment of the deformed hand shown in Fig. 10. Two operations elsewhere had failed to release the contracted fingers and, although some improvement followed an attempt to relieve the contractures by the interposition of angle flaps combined with the application of palmar

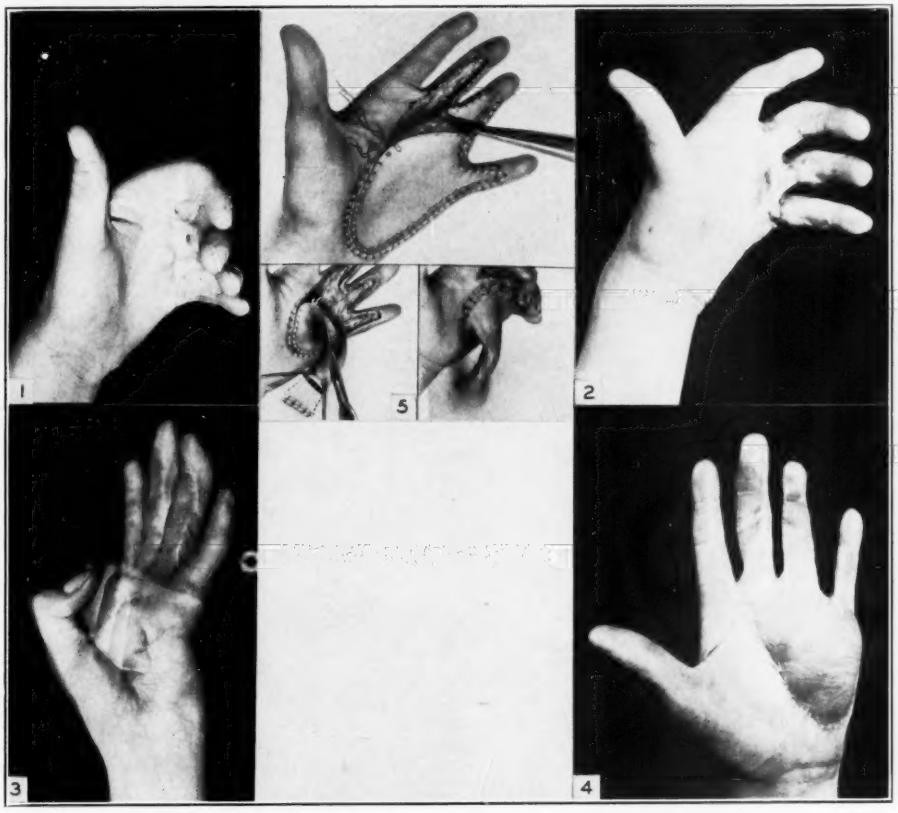

Fig. 10.—(History No. 77243, W. M., 6 years of age.) Two previous operations elsewhere had failed to release the contractures of the flexor surfaces of the fingers and the palm shown in *1*. This deformity of five years' duration was only partially corrected by the interposition of Z-flaps along the webs and the use of full thickness grafts with the result shown in *2*. The end result following complete excision of the cicatrix and the transplantation of a tube flap to cover the defect is seen in *3* and *4*. The technique of transplantation of the tube flap is shown in *5*.

full thickness grafts, it was necessary eventually to transplant a tube flap to the palm and fingers before a full range of motion could be obtained.

About the periphery of extensive scars there are often one or more band or weblike contractures. Release of these by the interposition of angle flaps usually makes the correction of the main scarred area

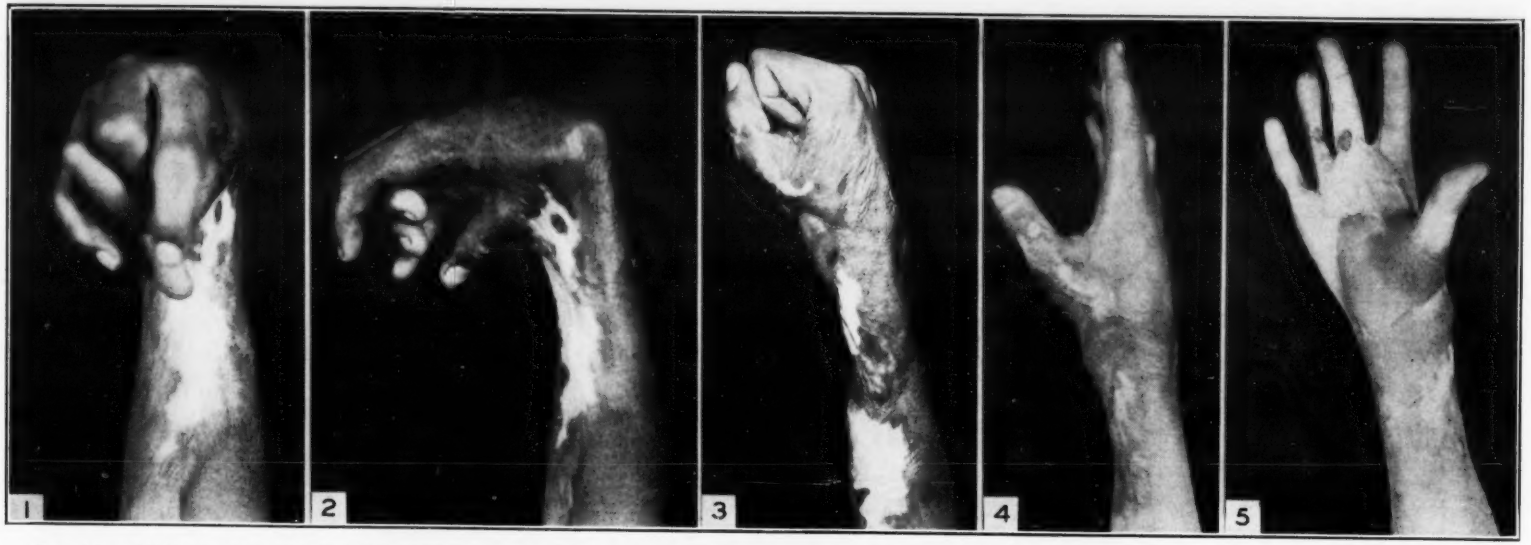

Fig. 11.—(History No. 25478, W. M., 13 years of age.) *1* and *2*, This contracture of eleven years' duration was released by the interposition of Z-shaped flaps along the web extending from the base of the thumb up the forearm combined with the use of a tube flap from the abdominal wall to reconstruct the proximal part of the palm. The result five months after operation is shown in *3*, *4*, and *5*.

easier and results in more normal tension after the deep cicatrix has been excised. The web at the wrist shown in Fig. 11 was released in this manner and the palm reconstructed by a tube flap from the abdominal wall. Frequently it is necessary to use this procedure in connection with the application of full thickness grafts to relieve contractures of the fingers.

The third type of contracture may be associated with damaged tendons or nerves, and with bone deformity. Kanavel,[6] Bunnell,[7] Mason,[8] Meyer and Ransohoff,[9] and Koch and Mason[10] have stated the principles to be followed in the management of these complicated problems and a discussion of this type of case is beyond the scope of this paper. Nevertheless, too much emphasis cannot be placed on the prevention of skin contractures following third degree burns by early restoration of the skin loss and early resumption of function. When the deeper structures are not damaged, the thick split graft of Blair and Brown answers this need better than any means yet devised; where the burn extends down to muscle, tendons, or bone, the use of a pedicle or tube flap is preferable.

In the management of old contractures proper physiotherapy and splinting with the use of elastic traction in cases of long standing is of greatest assistance in obtaining an adequate return of function. In the majority of the cases presented herein, it was found advisable for a splint to be worn at night for six months, maintaining and increasing the reduction of the contracture secured at operation. Gentle massage of a bland ointment into the scars for two to three months after operation increases their later pliability.

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RUPTURE OF THE MAIN BRONCHUS FROM EXTERNAL INJURY

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COLLECTED reports on injury to a bronchus from external trauma indicate that this accident is not uncommon but usually is fatal. In a brief summary of the literature, Jones and Vinson[1] found reports of twenty-one cases and added one of their own. Of these, nineteen terminated fatally.

Krinitzki's[2] case, the first recovery reported prior to 1939, was not diagnosed as rupture of a bronchus until twenty-one years following the injury, when an autopsy was made. The right bronchus terminated in a blind end 3 cm. from the tracheal bifurcation and was surrounded by fibrous tissue. For about 3 cm. beyond this there was complete absence of a bronchus, but distal to it the continuation of the right bronchus was found with its proximal end obliterated by cicatricial tissue.

In 1939, Jones and Vinson[1] had the opportunity to observe a patient with rupture of the left main bronchus from within a few minutes after the accident until complete recovery. At bronchoscopy there were observed evidences of extensive injury to the bronchial wall with progressive obliteration of the lumen. The entire left lung was atelectatic.

Two patients, referred to the Bronchoscopic Clinic, Jefferson Hospital, for pulmonary study, exhibited certain findings which suggested traumatic rupture of a bronchus. In the light of Jones and Vinson's[1] case it is the opinion that there was rupture of a bronchus with recovery in each case.

CASE REPORTS

CASE 1.—Man, aged 31 years, was admitted to the Bronchoscopic Clinic for study. His complaints were dyspnea on exertion and a sensation of oppression over the left chest. These were attributed by him to injuries sustained in an automobile accident four months previously. Accurate data concerning the patient's condition immediately following the accident are not available. Dr. M. C. Palmer, who saw the patient several days following the accident, noted the presence of cyanosis and marked shortness of breath. There was subcutaneous emphysema over the left upper chest anteriorly. There was a fracture of the first rib, left side, also of the left arm. Chest examination was difficult, but there were noted signs of either a massive left pneumonia or atelectasis. The right lung appeared normal. The absence of fever and other clinical data seemed to support a diagnosis of atelectasis. The patient was treated expectantly and was able to return to his home about ten weeks later.

When admitted to the Clinic, the patient was afebrile. He appeared in excellent condition and exhibited dyspnea only on exertion. The left chest appeared flattened.

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There was practically no respiratory movement. The trachea was displaced to the left. The apex impulse of the heart was localized in the fourth left interspace, midaxillary line. The right border of the heart was localized along the left sternal border. The right lung appeared to extend to the left of the midsternal line. A diagnosis of atelectasis of the left lung was made. This was corroborated by a roentgen-ray study of the chest (Fig. 1).

At bronchoscopy there was noted marked displacement of the trachea to the left. The right bronchus appeared normal except for distortion. The left main bronchus terminated in a blind pouch about 4 cm. beyond the carina. The mucosa appeared slightly pitted; no bronchial orifices or other communications were observed. Exploration with a filiform-tipped bougie corroborated this. Iodized oil was instilled for lung mapping (Fig. 2). A diagnosis of atresia of the left main bronchus of unknown origin was made.

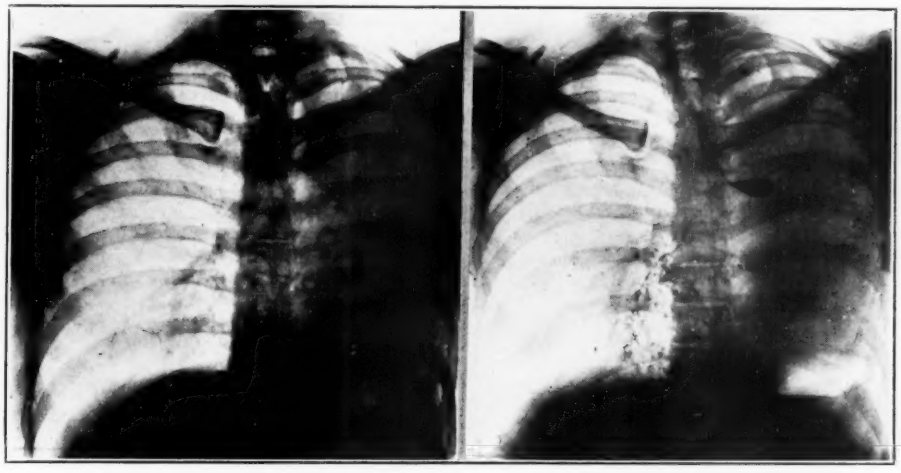

Fig. 1. Fig. 2.

Fig. 1.—Roentgenogram showed atelectasis of the entire left lung with displacement of the trachea and heart into the left chest. The right border of the heart is to the left of the sternum.

Fig. 2.—Roentgenogram made following instillation of iodized oil showed the rounded, slightly dilated left bronchus completely obstructed about 3 cm. beyond the bifurcation. There was marked displacement of the trachea and bronchi to the left side. Some of the iodized oil overflowed into the right bronchus. The bronchi appeared normal but are displaced beyond the midline into the left chest (reports by Dr. W. F. Manges).

At a subsequent examination pneumothorax was performed. The initial pressure was in excess of minus 16 cm. of water. Over 2,000 c.c. of air were introduced with no untoward effects; instead, the patient was no longer dyspneic and the sense of oppression was relieved. Paralysis of the left diaphragm and partial thoracoplasty were subsequently recommended. The patient left the hospital and failed to return.

Comment.—When the patient was first observed, the absence of fever and other signs and symptoms of pulmonary suppuration suggested that the atelectasis was in no way connected with the injury and probably was congenital in origin; this in spite of the fact that there were no respiratory symptoms prior to the accident, that the patient previously had been in good health, and that he had been accepted for military service. In view of the report by Jones and Vinson, this patient undoubtedly sustained an injury to the left main bronchus at the time

of the accident which ultimately resulted in atresia of the left main bronchus unassociated with infection of either the left bronchus distal to the point of injury or the left pleura.

CASE 2.—Boy, aged 9 years, was admitted on June 22, 1931, for study to ascertain if general anesthesia could be administered safely for tonsillectomy. In a routine chest study his physician, Dr. D. H. Solo, had found the heart in the right chest with atelectasis of the right lung. Five years previously the patient was seriously injured in an automobile accident and sustained severe lacerations of the scalp, fracture of five ribs on the right side, and injury to the right lung. This was complicated by nonproductive croupy cough which persisted for a considerable time. Four years after the accident the patient was taken to a clinic because of cough. It was found that his heart was in the right chest and the right lung was collapsed. A bronchoscopy was advised but was refused.

When first observed at the Bronchoscopic Clinic, five years after the accident, there was found atelectasis of the entire right lung with displacement of the heart and mediastinal structures into the right chest, displacement of the trachea to the right, and compensatory emphysema of the left lung. The patient was comfortable. There was no dyspnea even with moderate exertion.

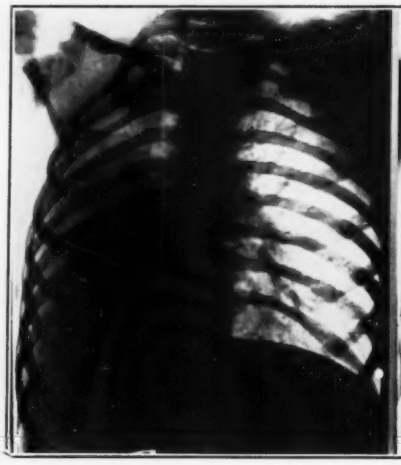

Fig. 3.

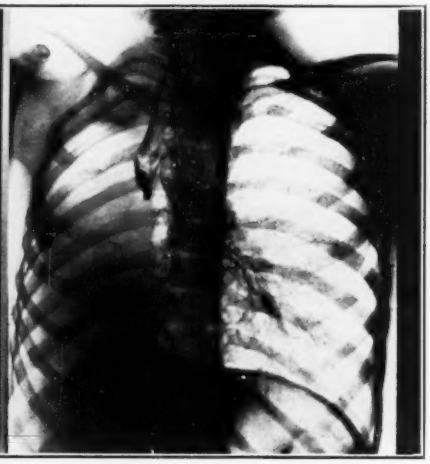

Fig. 4.

Fig. 3.—Roentgenogram of chest showed marked cloudiness of the right lung with the heart and trachea drawn into the right chest so that even at expiration the left border of the heart did not come to the midsternal line. The air column corresponding to the right main bronchus appeared to be interrupted about 2 cm. beyond the bifurcation of the trachea.

Fig. 4.—Roentgenogram made after bismuth subcarbonate was insufflated showed some irregularity in outline of the right bronchus which is completely obstructed at about the level of the upper lobe bronchial orifice (films by Dr. J. T. Farrell, Jr.).

A roentgen-ray study revealed remarkable displacement of the heart into the right chest with interruption of the air column of the right bronchus and apparently atelectasis of the right lung (Fig. 3).

At bronchoscopy there were noted displacement of the trachea to the right, some deformity of the carina, and complete atelectasis of the right main bronchus at a point slightly more than 1 cm. beyond the carina. The interior of the right bronchus appeared irregular; there was a slight depression on its outer wall. Palpation with forceps and a filiform bougie revealed no communication beyond this point. At a subsequent bronchoscopy these findings were corroborated. Bismuth subcarbonate was insufflated for lung mapping (Fig. 4).

In a recent follow-up made eight years after he was first observed and thirteen years after the accident, the patient, now 17 years of age, appears normal and leads a normal life. He is free from respiratory symptoms. The right chest is flattened and smaller than the left. The physical signs are practically identical with those observed eight years previously.

A roentgen-ray examination made by Dr. Karl Kornblum was reported as exhibiting appearances quite similar to those observed in 1931. There is evidence of retardation of growth of the right hemithorax with secondary scoliosis of the upper thoracic spine.

Comment.—The history of injury to the chest, the development of atelectasis, and the bronchoscopic findings indicate that the bronchial atresia was traumatic in origin. Failure of untoward developments over a period of thirteen years after the accident would also indicate that bronchial injury in the absence of excessive hemorrhage, tension pneumothorax, or suppuration is not incompatible with life.

The mechanism of traumatic rupture of a bronchus is not clear. In a number of the reported cases there was compression of the chest. In about 50 per cent of cases there was associated injury to the ribs. In discussing bronchial rupture, Schönberg[3] directed attention to two important factors; first, the compression of the bronchus between the elastic chest wall anteriorly and the rigid spine posteriorly; and, second, the marked increase in intrabronchial pressure due to the fact that at the time of impact the lungs are in the inspiratory phase with the glottis closed. In addition, the bronchi, being less resilient than the lungs and more or less in a horizontal position, suffer the more.

In the two cases reported there was injury to the ribs. In one, there was subcutaneous emphysema. There are no available data regarding the presence of pneumothorax. The histories suggest that no bronchopulmonary suppuration developed.

Conclusions.—Two patients with atresia of a main bronchus and atelectasis of the corresponding lung following severe injury to the chest and fracture of one or more ribs were studied.

There was no evidence of bronchopulmonary suppuration. One patient was symptom free, the other complained of dyspnea on exertion.

Traumatic rupture of a bronchus is compatible with life provided the patient survives the immediate effects of injury; namely, shock, hemorrhage, tension pneumothorax, and the possible development of suppuration.

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THE PLASMA POTASSIUM FOLLOWING INTESTINAL OBSTRUCTION IN DOGS

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Scudder, Zwemer, and Truszkowski[1] have reported a rise in blood potassium to lethal levels in cats following obstruction of the intestine at various points. They have suggested that potassium is the toxic factor sought for in acute intestinal obstruction. These observations have been extended to patients.[2] In twenty untreated cases of intestinal obstruction plasma potassium was raised in seven, and lowered in five. They concluded that disturbances in blood potassium explain some of the symptoms found in intestinal obstruction. They have recently reported other observations in support of the view that change in blood potassium plays an important part in deaths due to intestinal obstruction. Potassium determinations were done by the silver cobaltinitrite method of Truszkowski and Zwemer.[3] This work has attracted wide attention.[4, 5]

Cutler and Pijoan[6] have described a progressive rise in potassium in four dogs following high obstruction. No details of methods used were given. Bisgard, McIntyre, and Osheroff,[7] using a cobaltinitrite method, have reported that they found no constant change in plasma potassium in dogs following high obstruction. Thus, the theory that a high blood potassium plays any important part in bringing about death following intestinal obstruction rests on conflicting evidence.

We have followed the level of plasma potassium in twelve dogs with intestinal obstruction. Usually the obstruction was performed about 2 inches below the opening of the common bile duct. In one animal the obstruction was performed just below the ligament of Treitz.

In six of the animals the estimations were done by a silver cobaltinitrite method similar to that of Truszkowski and Zwemer, but slightly modified and using 1 c.c. of plasma. The determinations in the group were usually done in triplicate. The determinations on the second group were done by a modification of Shohl and Bennett's[8] chloroplatinate method, the details of which were kindly supplied by J. Manery Fisher. This always gave checks within 3 per cent, and usually within 1 per cent. Recovery of standards was always within 1 per cent and addition of sodium chloride did not affect recovery. All determinations were done in duplicate on 1 c.c. portions of heparinized plasma. The first group was compiled by one of us (R. E. H.) in 1938, the second by another in 1939.*

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*We are indebted to Miss L. M. Roddy for many of the determinations in the second group.

TABLE I

PLASMA POTASSIUM (MG. %) FOLLOWING INTESTINAL OBSTRUCTION

DOG	PRE-OPERATIVE	DAY 1	2	3	4	5	6	7	8	9	10
SO 13	19.4	15.0	14.4	18.0	21.2 16.1	24.8	obit. 18.0				
SO 15	19.3	19.0	16.5	16.6	15.4	14.8	15.1	16.6	20.7	obit.	
SO 17	19.5	16.0	15.8	15.0	17.9	17.4	18.0	16.8	17.8	16.9	20.2 obit. 19.3
SO 18	18.0	15.2	–	12.6	12.6	15.4	13.5	12.9	14.7	14.4	obit.
SO 19	18.1	13.7	15.0	16.4	obit.						
SO 20	17.8	13.6	–	16.1	17.3	obit.					
19/39	18.7	16.7 20.0	15.5 20.0	13.2	18.7	obit.					
21/39	22.0	17.6	24.0	obit. 14.5							
22/39	20.0	13.4	12.0	13.2	obit.						
20/39	21.9	–	–	20.0	17.5	–	15.4	–	13.7	obit.	
23/39	17.3	13.8	10.9	obit.							
24/39	20.9	15.2	13.8	obit.							

The results of the two groups, which are presented in Table I, are similar. All our animals showed a fall in plasma potassium of from 17 to 40 per cent of the initial value in the first few days after operation. In most instances the plasma potassium levels rose prior to death, but in only five of the twelve animals did the last determination exceed the preoperative value. The highest value obtained was 24.8 mg. per cent. However, no particular effort was made to be certain of getting blood in the last few hours before death. Consequently we cannot say whether or not a terminal rise in plasma potassium occurred. A few specimens of blood taken post mortem have shown very high values. It would seem probable that a premortal rise could be observed in this and in many other conditions, but it does not seem logical that a change which occurs when the animal is obviously moribund can be anything more than a *coup de grace*.

The observations reported above indicate that in dogs changes in plasma potassium do not play an important part in causing death following acute intestinal obstruction.

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Recent Advances in Surgery

CONDUCTED BY ALFRED BLALOCK, M.D.

BLOOD TRANSFUSION

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THIS form of intravenous therapy remains increasingly important to nearly all forms of medical practice. Surgery is particularly indebted to it, not only surgery of the emergencies where transfusion may prove lifesaving, but also surgery of election which has been expanded manyfold by the support of its preoperative, operative, and postoperative uses. Transfusion has consequently increased in frequency until every surgeon must have a certain knowledge of the subject and usually wishes for a more comprehensive account than that found in the textbook. Since the literature is voluminous, and on the whole individually concerned with special phases, this communication is undertaken to bring to date a brief survey of the literature. This is done with the realization that every day brings some change.

HISTORY

The term "life's blood" connotes not only that without blood one cannot exist but that with a full measure one may live. This idea of the paramount value of blood and its intermingling with the substance of life itself originated so far back in antiquity that it is intimately associated with writings of nearly all periods, modern and ancient, medical and lay. It was a prominent ingredient of many of the earliest pharmaceuticals, but the closest they came to actual blood transfusion was the practice of drinking large quantities of raw warm blood.[13] A notable historical mention is that of the unsuccessful attempt at prolonging the life of Pope Innocent VIII[24] by having him drink the blood of three young boys who were exsanguinated for the purpose.

The quasi magic, religious, and scientific conglomerate motivating therapeutics at the time transfusion was first suggested as such by Cardamus[13, 14] in 1556 is further illustrated by his suggestion that the "hopelessly immoral" be transfused with the blood of the "strongly moral." Sixty years later, William Harvey[13, 64] lectured on the circulation of the blood and following his first publication in 1628 a lively interest was aroused. Francesco Folli performed the first transfusion in animals in 1654; Daniel, of Leipzig, repeated this ten years later,

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to be followed by Lower, of England, the next year. He used a cannula for the first time. Jean Deny,[13, 57] of France, transfused a man with lamb's blood in 1667 and was the first to note hemoglobinuria. Many others rapidly followed until so many deaths occurred that the practice was prohibited by law or public fear for over one hundred years.[13]

In 1818 James Blundell[12, 13] used a cannula, added a two-way stopcock, and was bold enough to transfuse from man to man. He gave Goodridge credit for using the syringe method an indefinite time before. Blundell[13, 64] showed that a small quantity of air was harmless when injected intravenously, while Oré proved the fatal results from the injection of large amounts. Bischoff[12, 13] was the first to introduce a distinctly indirect method in 1835. He employed defibrinated blood. This practice was quickly taken up by many others and henceforth the two systems paralleled one another, each with its various modifications until the use of anticoagulants gradually forced it into oblivion.

Little in the progress of technique or study seems to have followed until 1869 when Buchner[13] defined the hemostatic effects of transfusion. Then followed another fruitful period. In 1871 Loewenthal repeated Oré's earlier warning of the dangers of air embolism. Higginson, Aveling, Gesellius, and Leisrink used glass cannulae and syringes. In 1875 Landois used cannulae and tubing from vein to vein. He, together with Prevost and Dumas,[13] first pointed out the dangers of transfusing species and showed that this was due to dissolution of the red blood cells of one species by the fresh serum of another. At the same time, Landois and Koehler and Gesellius and Ponfick condemned but continued to use defibrinated blood. They stated that reactions were due to "excess fibrin ferment"; Landois was the exception in practice and continued to use direct transfusion. About this time (1875), normal saline solution was first used intravenously and anticoagulants were then suggested. Braxton-Hicks proposed sodium phosphate and Richardson suggested minute quantities of ammonia[13] in an effort to avoid defibrination.

A lull in activity followed until the turn of the century. No one could explain or predict the accidents of transfusion, and its value and place were not clear in the face of these difficulties. It remained largely experimental and heroic, to be practiced almost entirely in isolated instances. With the almost simultaneous discovery of isoagglutinins by Landsteiner and Shattuck[37] and the grouping of all human blood into three classes by the former a year later, a renaissance began. Jansky discovered the presence of a fourth group in 1907. Landsteiner, Sturli,[24, 57, 64] and Decastello[19] arrived at the same conclusion independently about that time. Moss, using a third separate and numerical classification, demonstrated that almost invariably hemolysis paralleled agglutination. Hektoen and Ottenberg confirmed

these observations to complete the explanation of incompatibility and by the mechanism of proof furnished a practical method of avoiding lethal reactions.[12]

Shortly before (1899) and continuing through the same period, Murphy, Carrel, and subsequently Crile, Guthrie, and many others, perfected the technique of accurate blood vessel suture.[13] These two accomplishments promoted the first real practical therapeutic progress in the use of blood transfusion. Artery to vein, vein to vein, and then cannula and tube from vein to vein became technically more dependable and certain of success. These direct methods, paralleling the indirect one of using defibrinated blood, remained the procedures of choice until 1914. Curtis, David, and Kimpton-Brown augmented the direct method by employing paraffin-lined glass bulbs and tubes. In 1913 Lindeman[61] revived and popularized the multiple syringe technique. Freund, Kush, and notably Unger introduced pumping devices with the two way stopcock. Concurrently, Ottenberg, Kaliski, and Friedman[12] added to the knowledge of isoagglutination by pointing out that the repeated use of the same donor for the identical recipient caused the development of abnormal isoagglutinins and hemolysins. Two years later, Ottenberg and Libman[12] postulated the necessity of cross-matching by describing hemolytic reactions with hematuria predictable only by such a test immediately before transfusion.

Prior to 1914, anticoagulants had not been successfully employed. With the nearly simultaneous and independent discovery of the use of sodium citrate, first by Agote and then by Weil, Ruesch, and Lewisohn, indirect transfusion became widely used.[19] It has gradually emerged as the method of choice almost universally. It remained for Lewisohn to rationalize the technique and quantitative measurements in its employment.[22, 23]

From this time to 1929, there occurred an enormous increase in the use of intravenous blood as a therapeutic agent. Concurrently myriad contributions of good and bad technique and modifications appeared, and as many studies and opinions flourished concerning reactions, isoagglutination, and anticoagulants. One is awed by the quantity and quality of evaluations of the place and value of blood transfusion.

During 1927 and extending to 1929, Shamov[1-3] found and proved that the cadaver of a dog could be kept for more than twelve days without contamination of the systemic circulation if it were refrigerated at 0 to 3° C. He also significantly rediscovered that, if the animal died an asphyxial type of death, no anticoagulant was needed, and that the blood thus obtained from these dogs could be transfused into living dogs previously exsanguinated to 60 to 90 per cent of their blood volume without toxic, in fact with satisfactory, effects. In many respects Shamov revived earlier experiments and suggestions of storing blood made first by Hedon in 1901[31] and subsequently in 1914

by Abel[35] who mentions Nagel's transfusion of dogs with refrigerated four-day-old cell suspensions. Lardenois transfused dogs with four-day-old citrated blood about 1916; Panum and Cornu prolonged the experiment to show that red blood cells could be preserved for as long as three weeks. Robertson[56] performed twenty-one transfusions in 1918 in a military hospital. However, Shamov's experiments were the first clean-cut and complete of their kind.

Yudin, acting on Shamov's dog experiments, and beginning in 1928, employed human cadaver blood for heroic transfusions in man. Following the confirmation of Shamov's work and the addition of gaseous exchange experiments by Barendoim and Skundina in 1931 to 1932, cadaver blood found wide usage in Moscow until Bruskin and Forberova reported the employment of stored placental blood in 1936[8] concurrently with others. Since then, stored, citrated, placental blood have gained international usage.

Shortly after publication of the work of Shamov and Yudin in 1928 to 1932, Jeanneney, Servanti, Jullien-Viroz, and soon many others began working with the transfusion of stored donors' blood. Since their publications in 1934 and again in 1936,[4] many elaborate systems of storage and organization have developed throughout the world. These systems and the use of stored placental blood are fast replacing the employment of professional donors.

METHODS OF TRANSFUSION

Many of the systems referred to above are not employed today but simply represent stages in the development of current procedures. Transfusions now are done by using one of two methods: (1) direct, using unaltered blood, and (2) indirect, using altered blood.

Direct Transfusion.—This means the use of whole or unaltered blood by any of the three following techniques: (1) Goodridge-Lindeman, or multiple syringe; (2) pumping devices, such as the Unger apparatus; (3) paraffin-lined glass tubes, such as the Kimpton-Brown or Vincent tubes. All direct methods depend on technical speed in transfusion sufficient to transfer the blood before coagulation has time to take place.

Indirect Transfusion.—This infers that blood is taken from a donor, altered in some fashion to remove, avoid, or prevent the formation of coagulum, and given leisurely, quickly, or stored, as desired. The three basic means of altering blood are by defibrination, by allowing cadaver blood to alter itself by autofibrinolysis, and last by the addition of anticoagulants either to the donor before drawing blood, as with heparin, or to the blood as it is drawn.

The first of the three methods of indirect transfusion, the removal of coagulum, is accomplished by defibrination. This is done during the process of clotting, as the blood is drawn. The fibrin network is

broken away from the serum and cellular elements into compact masses which are filtered off. This is accomplished either by shaking with glass beads or by stirring or whipping, usually with a glass rod. This process unfortunately forms a sufficient number of minute fibrin masses too small to be caught by a filter coarse enough to allow passage of the red blood cells themselves. These smaller masses of fibrin give rise to chills[37, 38] and are the "fibrin ferments" referred to by Landois and co-workers. For this reason and because the often desirable hemostatic effects are minimized by fibrin removal, this method of indirect transfusion is now a point of history reserved for use in emergencies where modern apparatus and anticoagulants are not available.

The second method of indirect transfusion, that of avoiding coagulum, takes advantage of a long known phenomenon relative to coagulation of blood in persons dying an asphyxial type of death, such cerebral violence causing respiratory paralysis, fatal coronary occlusion, strangulation. The blood remains fluid in the body until drawn, coagulates almost immediately, but within sixty to ninety minutes the fibrin network undergoes fibrinolysis. The mechanism of this spontaneous autolysis does not appear to be understood,[1-3] but the blood will never coagulate again and may be handled and stored the same as stored donor or placental blood to be described later. In times of war or famine, where donors are inadequate in number or quality, cadaver blood certainly has a place. In the future, social custom may demand its use in civil life.

The third indirect method of transfusion prevents coagulation with the use of anticoagulants. This divides itself into two schemes: one of adding a substance to the blood as it is drawn, and the other of dosing the donor with an anticoagulant before taking the blood. Many anticoagulants exist, but only two so far have proved nontoxic to man when given in optimum amounts. These are sodium citrate and heparin.[25, 44] Transfusol, a complex sulfonate, has recently been used in Europe[21] and hirudin[34] may eventually be refined and used like heparin, but sodium citrate remains the anticoagulant of choice because of its relatively stable chemical properties, its ease of handling, and its low cost.

There are two methods of administering an indirect transfusion to the recipient. The first is to use various containers with reversible pumps and to give the blood rapidly. The second is the intravenous gravity drip familiar to all and undoubtedly the one of choice as will be detailed later under a discussion of reactions. The speed of this drip varies from forty-five to sixty drops a minute to a continuous stream, depending on the relative need for speed in the condition requiring transfusion. One is warned to avoid heat jackets and hot water bottles because of the danger of partially or completely coagu-

lating the blood. The transfusion may be preceded by a small quantity of saline solution for convenience.

TECHNIQUE OF TRANSFUSION

A. *Direct Transfusion.*—

Returning to whole blood or direct systems of transfusion, it seems obvious that the technical difficulties necessitate a trained transfusionist or team to assure efficiency.

1. *Multiple Syringe:* One of the simplest techniques is that of Lindeman using multiple syringes. This requires a team of three, preferably four. The donor and recipient are placed side-by-side with the operators between. Appropriate arm boards and sterile drapes are placed, the subjects' arms are prepared to expose a sterile field from just above the antecubital surface half-way to the wrist. A tourniquet consisting of a blood pressure cuff is applied to the donor's arm and pumped up to read about twenty points above diastolic pressure. If a blood pressure cuff is not available, a rubber tourniquet is placed just loose enough to permit a full radial pulse. In any event, the quality and rate of the radial pulse of both donor and recipient should always be checked to establish a base line for comparison as the transfusion progresses. This is all important to the recipient, since fatal or severe reactions are most apt to affect the pulse even before untoward symptoms develop. Number 14 to 18 gauge needles with stylettes (Unger) or without stylettes (short straight bevel needles) are used. The recipient needle may be fitted with a two-way stopcock to prevent air embolism while changing syringes. Needles and syringes are washed with 2.5 per cent sodium citrate or with normal saline solution as originally used. The needles are then inserted well into the vein of donor and recipient. The insertion of large short bevel needles is accomplished in two hops, first through the skin into the subcutaneous tissue through a minute slit made just lateral to the vein with a stylette-pointed knife, to avoid plugs of skin being punched out by the needle and to avoid injury to the vein. The needle is then moved to the side or directly over the vein, whichever approach is preferred by the operator, and the patient asked to make a fist to distend the vein. The final push is a quick hop if the needle is shovel-nosed, and the feel is that of freeing the needle point completely from any resistance just as when one hits the subarachnoid space in spinal puncture. If an Unger type of needle is used, the push is steady until a free flow of blood is obtained, and not a hop lest one injure or go through the opposite vein wall entirely. The donor needle may be inserted against the direction of flow of blood, i.e., toward the fingers instead of toward the shoulder, so the stream does not have to go around the corner. This nicety delays the formation of small plugging clots about the needle and facilitates the speed of transfusion. If the syringe pistons

fit with precision, the donor is able to fill the syringe himself with augmented venous pressure by slowly opening and closing his fist. He does this by command as each syringe is filled and actually increases the rate of arterial flow and further speeds the transfusion. Twenty cubic centimeter syringes are used, and as each is filled they are passed to the recipient operator, then to a third or intermediary, who washes them free of blood in a basin of normal saline solution, and finally back to the donor operator, completing cycle after cycle until the desired amount of blood has been given. The recipient operator, or the fourth person who is checking the recipient's radial pulse, keeps the team synchronous by counting, both to note the quantity and as a signal to control the speed of the donor operator. This same person not only checks the character of the radial pulse of the recipient but also his color and respiratory rate, and notes immediately any subjective symptoms of reaction, such as dyspnea, substernal oppression, faintness, and lumbar pain. If the blood is given slowly during the administration of the first 20 to 40 c.c., most anaphylactic and agglutination reactions will show themselves. Fatalities have not occurred when amounts of blood under 100 c.c. have been given.

2. *Pumping Machines:* The Unger apparatus is used by a team of two, preferably with a third person acting as an observer of donor and recipient, as in the Lindeman technique. This third party may also play a stream of ether over the pump barrel and to-and-fro valve. Reducing the temperature in this part of the system lengthens clotting time appreciably. The setup is similar to that for the first technique. The apparatus is filled either with 2.5 per cent sodium citrate or, as originally, with normal saline solution to test the patency and direction of flow of the system, avoid exsanguination of the intended recipient, prevent air embolism, and obliterate dry surfaces which would both hemolyze some blood and hasten clotting. The needles are inserted as before, the recipient's tourniquet removed, and, while one operator works the pumping syringe and to-and-fro valve and counts, a second slowly syringes the recipient system with citrate or saline solution each time the pump is filling with donor's blood, to keep the tube and needle free. Many modifications of the apparatus exist, but they differ only in appointments rather than principle. The most recent variation is practically automatic and apparently more foolproof. The simplest modification consists of a circular crank or hand rollers on a rubber tube connecting the two needles.[150]

It is obvious that neither the Lindeman nor the Unger technique should be used in the presence of any type of bacteremia or septicemia, of which syphilis is one, or acute infectious diseases in the recipient because of the possibility of infecting the donor.

3. *Paraffin Tubes:* The various paraffin-coated glass tubes of Kimpton-Brown or the handier Vincent tube requires the precision of only one

operator and one assistant to check donor and recipient. This technique is free of the danger of contamination by the operator's changing of gown and gloves after he has inserted the recipient cannula. The method is based on the fact that paraffin, like any other wax surface, does not "wet" and therefore does not destroy the cellular elements of the blood. The liberation of kephalin and utilization of platelets is thus retarded to the extent that clotting is delayed beyond the usual five minutes, to twelve or thirteen minutes. The possibility of a plugged recipient needle delaying and possibly nullifying the transfusion by allowing the drawn blood to clot within the tube is avoided by using a "cut-down set" to insert a cannula in the saphenous vein at the ankle before the donor's blood is taken. The saphenous vein is invariably located between the internal malleolus and tibialis anticus tendon, making it easy to find and finally leaves no conspicuous scar if things go wrong. This vein is always large in proportion to other distal veins and has no associated cutaneous nerve to be mistakenly included in the cannula tie. The median basilic vein in the arm is often so intimately associated with a branch of the antecubital nerve that, if the nerve is not carefully isolated, it will be included in the cannula tie and will result in pain and anesthetic areas for some days or weeks. A rubber bulb from a medicine dropper is filled with 2.5 per cent sodium citrate solution, fitted over the end of the cannula, and gently squeezed, just enough to flush out and fill the needle shaft and adapter. A No. 13 to 16 gauge needle is attached to the snout of the paraffined tube; 50 c.c. of a 2.5 per cent sodium citrate solution is poured into the tube and the blood taken from the donor without agitating it. The citrate will float on top, keeping air from the blood, further to lengthen coagulation time and, if difficulty in taking blood should slow the process beyond the usual five to eight minutes, the citrate may then be mixed by agitation of the tube to avoid entire loss by clotting. A reversible pump* may be attached to the Vincent tube for suction to speed the taking of blood and to keep the needle free. Adequate tourniquet pressure, together with slow rhythmical contraction of the hand into a fist alternating with relaxation, is usually sufficient for rapid blood-letting and one is often warned of impending syncope of the donor by stoppage of the flow. Though some[11] recommend ephedrine and continuation of blood-letting in spite of fainting, it seems reasonable to stop as the writer has seen two instances of shock result after what appeared to be only transient syncope. The usual 500 or 600 c.c. is taken in this manner and immediately pumped into the recipient through the previously inserted cannula. When the level of floating citrate is reached, the transfusion is discontinued. The advantages of this technique over the preceding ones are the pro-

*A word of caution: if the pump is reversed by accident, the donor will receive a large sudden dose of citrate and possibly air, which a tourniquet may not completely keep from his systemic circulation, either of which may kill the donor.

tection from infection given the donor and the necessity of having only one trained operator instead of two or three. Its disadvantage is the impossibility of waiting to see the effects of the first 20 to 40 c.c. administered before the full amount is given. This may be overcome by discarding the cannula, mixing the blood with citrate, and giving by the usual intravenous drip, becoming, in fact, a good indirect transfusion technique.

Although many still cling to one of the above procedures or slight modifications of these direct transfusion methods, such precision is required as to render them impracticable, unsure, and oftentimes dangerous to the recipient or donor or both. The advantages claimed for unaltered blood transfusion find little support in fact. Any anticoagulant, if used in optimum strength, is so diluted and altered as to have no appreciable effect on the recipient's clotting time; in fact, there appears to be some evidence to show that citrated blood exerts more coagulant effect than whole blood alone.[22, 23]

B. *Indirect Transfusion.*—

Altered blood or indirect transfusion is now used extensively. The technique of taking and giving blood differs only in minor details, but the treatment of the blood before or between the two maneuvers varies widely.

1. *Citrate Method:* Schemes of drawing citrated blood should be as simple as possible and yet conform to certain general requirements. Closed systems are preferable to minimize contamination and to retard coagulation. The entire apparatus may be washed with paraffin on the inside like the Vincent tube to retard coagulation further. A suitable donor vein is chosen, the entire apparatus to be used including the needle is "citrated," and the blood is drawn. Blood and citrate are mixed by swirling and not by shaking or stirring, since a certain amount of defibrination is apt to occur. If blood is drawn rapidly enough to complete the procedure within the allotted five to eight minutes, 35 to 40 c.c. of 2.5 per cent sodium citrate solution to every 250 c.c. of blood is adequate. Excessive amounts of citrate are to be avoided since this may give rise to serious reactions.[29] The minimum amount of citrate is 25 c.c. to every 250 c.c. of blood, but few find this practical because, if blood is taken slowly or difficulties are encountered, approximately 50 c.c. of citrate per 250 c.c. of blood are required to prevent the formation of coagulum. This is probably due to the excessive liberation of kephalin, which produces large amounts of prothrombin, to the failure of all the blood calcium meeting citrate with which to react, and to individual differences in blood calcium values. Hot or dry sections of an apparatus, long tubes, or trapped bubbles promote rapid coagulation and hemolysis, the same as hypotonic solutions, such as distilled water, produce immediate hemolysis. It is preferable to filter the blood by gravity and not pump pressure. This avoids

forcing small clots through the filter. Squeezing clots to obtain the last few cubic centimeters of blood gives chills for one's efforts because of the minute fibrin clots formed, the same as forced filtration.

2. *Storage:* If blood is to be stored, salvarsan tubes of 375 c.c. capacity are preferable to flasks because it has been shown that the rate of hemolysis is proportional to the area of interphase between the plasma and cellular elements. These are filled to within two inches of the top to avoid wetting the gauze used as a cover. These storage tubes are rinsed with citrate before receiving blood for the same reasons given for citrating the drawing apparatus. Recently it has been shown that the hydrogen-ion concentration of the citrate also influences the amount and rapidity of hemolysis;[45] consequently, the hydrogen-ion concentration of the citrate and saline solutions used is to be adjusted with citric acid or 10/N sodium hydroxide so that after autoclaving it ranges from 7.1 to 7.5. Excessive amounts of citrate also hasten hemolysis.[63] The consensus relative to storage temperatures is a range from 0 to 4° C. The physiologic principles involved in the storage of blood are that refrigeration reduces the cellulary metabolism nearly to zero, inhibits and apparently destroys bacterial growth,[7, 8] and inhibits plasmolysis and hemolysis. When stored blood is to be used, it is heated very slowly in a warm bath to bring it to body temperature. This may be done while waiting to check the cross-match, but, if an emergency exists, the blood may be given cold without fear. Stored blood always separates into three layers within a few minutes to hours, depending on its sedimentation rate. The top layer is clear plasma; then comes a muddy layer of plasma and cells and finally a solid sediment of packed cells. The degree of hemolysis during storage is checked by inspection of the supernatant portion of plasma before agitation and then comparison with a set of standards after centrifugation of the sample to be used for cross-matching. The supernatant layer gained by centrifugation may be accurately checked with a Plufrick photomeyer,[62] but inspection alone is practically sufficient. So far no one has set an accurate limit on the maximum hemolysis allowable to avoid reactions, but after eighteen days of storage a sharp rise in the number of reactions, regardless of the amount of hemolyses,[63] takes place. During storage, blood should not be disturbed by agitation or warmed by standing at room temperature, since both agitation and heating promote hemolysis. This is due to the fact that red blood cell fragility increases rapidly with storage time.[30] The fragility of stored blood contraindicates the use of diluting fluids, such as saline solution, and a minimum amount of saline solution is left in the administrating apparatus when used to precede the transfusion.

The advantages of stored donor's blood are obviously its quick availability for emergency cross-matching, the opportunity of prior

typing, serologic testing for syphilis and abnormal agglutinins, inspection for malaria, inspection of donor for primary and communicable diseases and allergic history, and finally its great economy for patient and hospital alike. When blood approaches its end point of storage time, which is recognized by beginning hemolysis, it may be separated and the plasma used for immune serum or lyophile or as plasma to combat traumatic or operative shock or for use in the treatment of severe burns.[43, 55, 59]

3. *Heparinization of Blood:* Heparin has proved nontoxic only after careful refinement.[25, 41, 44] It is precipitated as a barium salt and the barium subsequently completely removed. It is given in doses of 1 mg. per kilogram of body weight in a 5 per cent solution to the donor and the blood drawn in ten to thirty minutes. If this dose is used, the recipient's coagulation time is not significantly changed and the donor's coagulation time returns to normal within 1.5 hours. The effect on the coagulation time of the drawn blood lasts for twenty-four hours. The cost of heparin at present is prohibitive, but eventually this method should find a limited place in blood transfusion. The technique of taking and giving the blood is simplified by its use. Any satisfactory closed system may be used for drawing the blood. Objections to giving heparin to the donor may be obviated by adding it to the blood as it is drawn, but this seems a defeatist's recommendation. Sodium citrate remains the anticoagulant of choice.

4. *Cadaver Blood:* Cadaver blood is taken by placing a T-cannula of large size in the jugular vein with an aseptic technique. The Trendelenburg position is then used, often combined with massage of the extremities toward the body. Finally, more blood may be obtained by washing the systemic circulation with normal saline solution. Such a solution contains about 45 per cent hemoglobin but may not be stored for long periods of time, since it hemolyzes more rapidly than whole blood. It is recommended that the blood be taken in from four to six hours after death if the body has been stored at 0 to 3° C. in the interim. The blood from the easily contaminated portal circulatory system does not contaminate the blood in the systemic circulation even up to twelve days of such storage.[1-3] Infections and open contaminated wounds contraindicate the taking of cadaver blood. Nine hundred to 1,500 c.c. of blood may be obtained from the average cadaver where injuries preclude the use of any but that contained in the immediate reservoir of the internal jugular vein. If the person were uninjured, thus eliminating the danger of contamination by massage, and there has been no loss by internal hemorrhage, between 3.5 and 4 liters may be obtained; the last 1,500 c.c. is secured by the method of washing described. Storage is the same as with citrated blood and transfusion is given by the usual intravenous technique.

5. *Placental Blood:* Placental blood is taken by one of two methods: either by cannulization of the umbilical vessels aseptically and letting it run into a closed vessel, or by simply draining it into an open vessel from the cut end of the cord. The cord is not milked toward the child in the usual manner before severance. The vessel preparation and citration are the same as for taking any donor's blood. However, many add an equal amount of Moscow diluting fluid instead of citrate. One hundred to 150 c.c. of blood may be obtained from each placenta and cause little if any delay in the delivery; like types are pooled.[25] The advantages of placental blood are not only those of stored blood in general but also those peculiar to itself; such blood coagulates 20 to 35 per cent faster than adult blood and has a red count of 5 to 7 instead of 4.5 to 5 million; its hemoglobin content is 90 to 120 per cent.[7, 8] The advantages of its selective use are obvious and its general use is feasible except where a larger volume of plasma is desired, such as in shock without actual blood loss.

SOURCE OF BLOOD

Sources of blood fall into four classes: professional, voluntary, cadaver, and placental.

Professional donor systems have previously formed the basis of efficient transfusion mechanisms in large communities. Nearly everyone is familiar with this scheme of routine physical examination, history, hemoglobin determination, typing, and periodic serologic testing of donors in formulating a call list. There is considerable variation in the interval of such examinations required to keep the donor on the list, but the essential framework remains the same. Donors are not allowed to give blood oftener than every eight to twelve weeks; they must be serologically tested every two to three weeks and must declare themselves free from acute infections and exposure to contagious disease upon call. When a donor is cross-matched with a recipient, he is then subject to whatever rules of call the transfusionist believes adequate for the welfare of the recipient. Most institutions tabulate reactions caused by donors, especially where Type 4 (Moss) (0 of international) or universal donors are used in an effort to eliminate those having a high titer of abnormal agglutinins. The disadvantages of such systems obviously are the cost, the impracticability in small communities, the possibility of clerical error, and the impossibility of being sure the donor is absolutely free of disease at the time of call.[55]

Voluntary systems are organized on the same basis as the professional in a few communities, notably London. The prevailing system is to individualize the problem, using relatives and friends of the recipient. The cost of the latter is only slightly less than the professional system in many instances of unusual type, due to the waste-

ful method of haphazard hunting at odd hours when prospective donors are available. There is the added inconvenience and expense of emergency serologic testing for syphilis. As a consequence, a recent survey found an appalling percentage of institutions not doing pretransfusion testing for this disease.[27] The excuse is the plea of emergency, yet the system itself defies every effort at emergency usage. Voluntary systems which are allowed to thus prostitute the safe practice of medicine are condemned, but the proper use of voluntary donors will remain a necessity until the more efficient system of storage is universally practiced.

A third variation of the voluntary system is that of the blood bank. Such a scheme depends upon an initial quantity of blood in each of the four types, citrated, catalogued, tested for syphilis, and refrigerated. Replacement of blood used is by the recipient on recovery or by a relative or friend at a convenient time before or after transfusion, and from the practice of therapeutic phlebotomy, notably on medical wards. The advantages of this system have been enumerated, but to these should be appended its ease of transportation between and within communities.

At present not only does tradition and superstition hamper the use of cadaver blood, but also its source is limited to those free from disease and open wounds, and also by delayed refrigeration of the cadaver. The final requirement of an asphyxial type of death narrows its practicability to large communities where many such cases are seen. One obvious advantage of cadaver blood over all other forms is the opportunity for accurate examination of the donor by autopsy. A controversial advantage given cadaver blood and stored blood in general is the surmise that unaltered protein in donor's blood undergoes enough autolysis or hematemic proteinolysis (digestion) to destroy its antigenic and therefore its allergic properties.

Placental blood is of increasing importance as a source of stored blood. However, its use is limited to hospitals possessing a large obstetrical service since the quantity from each placenta is so small.

REACTIONS

Clinically, nearly all transfusion reactions are febrile, immediately or after a latent period, and the great majority of such reactions are accompanied by a chill.

The most severe reactions are due to agglutination and may rarely be lethal before a febrile reaction can take place. Such reactions are dramatic in their acuteness and severity and usually take place after the first 20 to 40 c.c has been taken, if this is given slowly. Occasionally these severe reactions are delayed from ten to thirty minutes. The earliest indication is a dramatic change in the radial pulse, often accompanied by acute shock and a fall in blood pressure. Any one or

all of the following signs and symptoms are present in lethal and sublethal reactions: cyanosis, dyspnea or orthopnea, pallor, substernal oppression, pain in the lumbar region or down the backs of the thighs, apprehension, thirst, loss of consciousness, headache, and convulsions.

Hemolytic reactions either with or without sublethal agglutinations are usually ushered in by a chill during or shortly after the transfusion is finished. Rarely, convulsions come on with the onset of hemoglobinuria, a few to even twenty-four hours later. Occasionally a latent chill or simply a temperature rise of one to three degrees is seen in the first twenty-four hours following transfusion. In those who will suffer serious consequences, a slight to a very noticeable icterus is usually evident within twenty-four hours and reaches its maximum in forty-eight to seventy-two hours. The urine may quickly diminish in amount or cease until a uremic death ensues three to eight days later. The hemoglobinuria may be transient, soon to be followed, in desperate cases, by pus, albuminuria, debris, and granular casts. In such cases Lephene[60] stains of fatal cases show the convoluted tubules to be packed with acid hematine causing an obstructive type of nephritis. If the hydrogen-ion concentration of the urine is greater than 6, hemoglobinuria clears in a few hours with no further ill effects. Stored blood, especially if over 15 to 18 days old, commonly gives rise to a mild innocuous icterus which may or may not be accompanied by fever. The icterus usually clears in twenty-four to seventy-two hours without further event.

Asthma, urticaria, and headache may or may not be accompanied by a chill and seldom prove fatal since adrenalin usually affords quick relief. Rarely pulmonary edema develops and demands hypertonic sucrose intravenously.

In summary it must be said that the majority of transfusion reactions are immediately or latently febrile. Most of these are accompanied by a chill which in itself is of sublethal consequence save in the debilitated who may be unable to withstand the physical exertion of a rigor. The fact of a chill, however, not only points to a nullification of the expected hemoglobin rise but also may be the herald of a major catastrophe. For this reason it is well to consider a chill in the same category as any of the above-named, less common signs and symptoms until proved otherwise and to discontinue the transfusion immediately. If such precautions are followed and less than 100 c.c. of blood has been administered, a fatal outcome is exceedingly rare. One author raises the minimal lethal dose to 350 c.c.[5]

Reactions in transfusion are divided into five etiologic classes: those due to (1) incompatibility, which are most commonly chargeable to faulty or incomplete pretransfusion testing and cross-matching; (2) faulty technique in taking or giving the blood; (3) impure materials used, such as citrate, saline solutions, etc.; (4) carelessness in

preparing the apparatus; (5) allergy of the recipient for the donor's blood.

1. *Faulty or incomplete technique in pretransfusion testing and cross-matching* primarily refers to the latter since the desirability of donor examination for communicable diseases and testing for syphilis seems obvious beyond remark. It has been repeatedly shown that the major catastrophes and perhaps a major portion of the lesser reactions are caused by carelessness or failure to recognize agglutination or hemolysis or both in the cross-match or the dependence on typing alone or the use of a so-called universal donor without cross-matching at all.

A brief review of the subject of isoagglutination seems pertinent since an understanding of this phenomenon emphasizes the importance of transfusing within types and the use of meticulous cross-matching. Such a discussion has been premised by a brief history of the development of modern transfusion from the time of Landois' first recorded observation of interspecie "laking." Landsteiner, his co-workers, and his contemporaries have made this a science in itself, so wealthy in its literature that elaboration in this communication is not desirable. Isoagglutination, by terminology, refers to intraspecie agglutination. The phenomenon is explained by the attraction or reaction of one body or substance held naturally or occasionally induced in the plasma, called the isoagglutinin, and another body or substance held in the red blood cells called the isoagglutininogen. By their dissimilar attraction, the red blood cells clump as if by magnetism to form the densely compact masses familiar to all. Such clumping, if intravascular, during a transfusion, produces a vast intracapillary blockage amounting to infarction, and in itself is shocking and usually lethal. Human blood is classified by isoagglutination reactions into four major types which are strong and almost always major and distinct in character unless old or uncommonly weak typing sera are used. Isoagglutinins and isoagglutininogens may be absorbed or adsorbed by dissimilar or immunized cells or serum respectively for experimental purposes and the identification of subgroups and abnormal agglutinins. There are two subgroups identifiable as such by especially prepared sera; one of type A, called A_2; and one of type AB, called A_2B which are uncommon and so indistinct with the usual typing sera that one is apt to mistype them. This motivates the suggestion that every laboratory make an effort always to use high titer typing sera so that their presence may easily be suspected when the cross-match does not check. The simplest method of obtaining such supplies is said to be by using sera from persons suffering from reactions from horse serum. Unquestionably, unrecognized subgroups account for a small number of serious incompatibility reactions and a larger number of lesser incompatibility reactions.[47, 51] The factors responsible for type determination when properly classified into three

genotypes, A, B, and R, obey the Mendelian law of inheritance. There are two other factors called M and N[32, 36] which exist, independent of type, and are similarly inherited by assuming an added allelomorphic gene P.[39] These agglutinins are not recognized without immunity development, bear no relation to subgroups or so-called abnormal agglutinins or agglutininogens, and consequently have no apparent significance in transfusion.

Besides the above, there exist certain irregular or abnormal agglutinins and agglutininogens, some of which exist permanently and some temporarily in both recipient and donor. In the recipient they are notorious in blood dyscrasias. They are apt to accompany febrile diseases[40, 53] and may be bacterial or toxigenic. It is well recognized that the presence of these, especially when associated with a high fever, increases the chances of a transfusion reaction to about 40 per cent and 25 per cent respectively. The signs and symptoms of such reactions are most apt to consist of chills and fever often combined with hemolysis or agglutination. These reactions are not only disturbing to critically ill patients, but the purpose of transfusion is defeated. Because of this factor, small frequently repeated 150 to 200 c.c. transfusions are preferable and fewer reactions follow when the blood is given during a relatively afebrile interval. In the donors permanent irregular agglutinins have been observed in sufficiently high titer, especially in some universal (Type 4, Moss) (Type 0, international) donors, to give unpleasant and occasionally dangerous reactions.[50] Lethal reactions are almost entirely eliminated by careful cross-matching. Quite frequently, apparently very weak abnormal agglutinins assume increasing titers even to lethal levels when the same donor is used repeatedly. Such findings contraindicate both the use of universal and repeat donors without meticulous cross-matching. If repeat donors are used, it must be within five to seven days. Fatal results have been recorded from the use of repeat donors up to eighteen months. It has been observed that even such precautions do not always protect the recipient from lesser reactions from repeat donors. Perhaps these unpredictable reactions are due more to allergy than to agglutination. It is agreed that subgroup and irregular agglutination cause reactions in proportion to their strength of agglutination. Therefore, weak agglutinins probably are responsible for few major transfusion catastrophes.[58] Especially is this true if cross-matching is done at 37° C., at which temperature most weak agglutinins lose their powers. There are some,[47] however, who believe the detection of weak agglutinins is extremely important. They resort to centrifugation of 14 mm. tubes in which three drops of recipient serum are added to one drop of a suspension gained by adding three drops of donor's blood to 4 c.c. of saline solution in 0.2 per cent sodium citrate. The tube is shaken, incubated five minutes

at 37° C., centrifuged three minutes at high speed, and not only inspected for hemolysis in the resulting supernatant fluid but inspected after reshaking the cells by microscopic examination of a hanging drop for agglutination.

A second type of reaction in this class of a faulty pretransfusion testing is that from hemolysis alone. This type of reaction is a delayed or latent reaction. Hemolysis and agglutination usually go hand in hand and have been shown to parallel each other in some 90 plus per cent.[48] They are, however, separate processes and lately more and more departures from the parallel are being found. Aside from the above centrifuge test for hemolysis and that mentioned previously under technique of stored blood, no routine tests are in common use. Hemolysis produces free hemoglobin and has been shown to cause latent reactions by precipitation as acid hematine in the convoluted tubules of those persons whose urine assumes a hydrogen-ion concentration of 6 or less.[6] Immediate alkalinization of all recipients with hemoglobinuria with oral or intravenous soda bicarbonate seems desirable. Routine pretransfusion alkalinization is not generally practiced but may gain favor in the future. The writer has occasionally used soda bicarbonate in 60 gr. (4 gm.) doses before transfusion when emergency demanded stored blood in which there was slightly more hemolysis than is ordinarily thought to be safe. In these instances no apparent bad results ensued. The latent effect of this type of reaction is uremia, and the treatment is the same as for uremia from other forms of kidney damage. Late alkalinization hinders treatment by promoting generalized edema.

2. The second etiologic class of transfusion reactions is that from *faulty technique in taking and giving* the blood and probably accounts for many minor reactions. Unwitting partial defibrination, the squeezing of clots, excessive citration, contamination by open systems, partial hemolysis from dry surfaces in the apparatus or heating of containers with hot water jackets or hot water bottles enough to produce hemolysis or heat coagulation, and finally the error of using hypotonic solutions have been discussed in part.

Excessive citration may cause serious consequences by its own chemical reaction.[16, 17, 20] The explanation is sufficiently important to demand a review of Howell's theory of coagulation.[15, 26] The sequence is as follows: Kephalin, which is liberated from injured tissue and platelets, activates prothrombin, but heparin, variously described as a mucoitin polysulphuric ester or a complex phosphitide obtained by extracting beef liver or lung, is kephalin's antagonist acting as antiprothrombin. Prothrombin in the presence of ionizable calcium forms thrombin. Sodium citrate changes the ionizable calcium of the plasma to less ionizable calcium citrate. By this same reaction intravascularly excessive citrate robs the circulation of cal-

cium to the point of acute calcium want and subsequent tetany, vagus, respiratory, and finally myocardial paralysis. If excess citrate is given by the intravenous drip, large quantities may be taken without effect, since the body is allowed time to mobilize its calcium. If citrates have been given to the patient for therapeutic purposes—sodium and potassium citrate are common ingredients in cathartic and alkalinizing preparations—only small excesses in the transfusion may cause reactions of this type. This completes a twofold reason for the avoidance of excessive citration of blood and the slower administration by the drip instead of the pump or forced method. Sodium and potassium oxylate are more efficient anticoagulants by conversion of ionizable calcium to insoluble calcium oxylate, but by the same token they are far too dangerous for transfusion use.[18] Finally thrombin is converted to fibrinogen but may be stopped by hirudin, a powerful anticoagulant said to be a complex proteose obtained from extracting leech probosci. Fibrinogen is converted to fibrin as the end step in the reaction and oxygen is necessary for its completion.

3. *The use of impure materials* ranks with carelessness in preparing the apparatus in the number of reactions produced and these two factors probably account for the majority of minor reactions. Their importance and their prevention have been stressed, but certain important details should be added and some repeated.

The usual normal saline solution, so often used for convenience to precede the blood, must not be replaced by calcium containing solutions, such as Ringer's solution, in citrate transfusion or clotting will take place, as sodium citrate prevents coagulation by a quantitative chemical reaction.

The hydrogen-ion concentration of the sodium citrate and saline solution having an influence on the hemolysis of stored blood has been discussed. The percentage of the citrate solution varies from 2 to 3.8 per cent, the principal requirement being isotonicity or slight hypertonicity.

The chemical purity of the solutions involved should be stressed as in any other intravenous therapy. Freshly distilled water from which chemicals and pyrogen have been removed by adequate distillation is paramount, regardless of whether it is singly or triply distilled.[28, 42] In the average efficient still the most common cause of impurities coming over is inefficient or dirty baffle plates. Impregnated or inefficient filter paper or contaminated Berkefeld filters may be factors in the production of chills.

4. *Carelessness in Preparation of the Apparatus.*—All apparatus involved in taking and giving of blood should be thoroughly washed immediately after use, first by mechanical means and tap water to remove clots and then with distilled water.[28] All parts are rapidly drained and dried to avoid bacterial growth in any collections of

water, such as may especially occur if rubber tubing is coiled instead of hung vertically. It has been shown that at room temperature one or one and one-half hours allow enough bacterial growth of air organisms to generate a chill when converted by drying in the tube and autoclaving into pyrogen.[42] The inside of the needle shaft should be scoured with its stylette and bon ami to remove rust and clot.

Any new rubber tubing or stoppers are treated by boiling in 0.1 per cent sodium hydroxide for five minutes or soaking in 10 per cent for thirty minutes. This removes the powder and protein the same as is done for any other intravenous apparatus. Gauze to be used for filtering blood is rinsed in freshly distilled water and immediately autoclaved. If still wet when ready for use, it must be washed in saline or citrate solution to avoid hemolyzing the blood to be filtered since water is hypotonic.

5. *Allergic Reactions.*—The allergic reaction is not easily separable from the types of reactions just mentioned. Many isolated instances have been directly traceable to this phenomenon, but so far no clean-cut study has been made to clarify it. (I have started such a study but to date no conclusions can be specified.) It is probable that there are two factors, a permanent and a temporary. The presence of permanent allergens is apt to be predictable from a detailed history of the recipient, possibly checked by intracutaneous injection when seemingly important. The most common predictable allergic reactions come from food sensitivity, such as strawberry, juniper, sea food, and other proteins, such as milk and raw egg white. The latter has been shown to be postprandially absorbed unaltered into the general circulation through the route of the lacteals and thoracic duct.[9, 46] Other proteins are partially split into amino acids and highly complex lipids. Experience with such reactions has resulted in the common practice of starving the donor from two to four hours before donation. It will probably become evident in the future that more permanent allergens, such as horse serum and vaccines, play a part in these rather infrequent but dramatic allergic reactions.

Since the percentage of reactions is not only a measure of an institution's skill and precision in technique but is also all-important so far as the therapeutic efficacy of the procedure itself, the various methods and means of prevention should be thoroughly understood. It has recently been shown that a transfusion accompanied by a reaction is 50 per cent less effective in raising the hemoglobin than those given without reaction. The literature is full of discussions of the subject of transfusion reaction, and the wide variation in percentages and criteria given indicates not only a general lack of understanding of the procedure and its consequences, but a need for scrupulous precision on the part of all concerned, from laboratory technician to floor nurses and physician in charge. After one has familiarized himself

with the scientific information necessary to carry out successfully a transfusion, he must finally learn the art of transfusion, which means the almost unconscious attention to the minutest detail in each step.

INDICATIONS

The indications for transfusion are controversial in their details, but the consensus is that transfusion is indicated in the following:

1. All sudden gross hemorrhages, except cerebrovascular accidents, whether from trauma, tumors, infection, or blood dyscrasia. In the latter two conditions, just as in bleeding peptic ulcers, small repeated transfusions are preferred, unless the loss of blood has been too rapid or has reached a critical level at the time transfusion is done. The amount of each transfusion and the speed of administration have been discussed.

2. All anemias which cannot be combatted with specific medication at a sufficient rate to accomplish the desired therapeutic result. This particularly refers to pre- and postoperative blood transfusions, regardless of the cause of the anemia, whether due to jaundice, malignancy, or hemolytic drugs or infection. Such transfusions are not to be used indiscriminately but should fit intelligently into the plan of surgical attack. It has been shown that the maximum rise in hemoglobin occurs at the end of forty-eight to seventy-two hours.[49] This fact is utilized in spacing transfusions at two- to three-day intervals instead of daily and aids in dictating the time of pre- and postoperative transfusions.

3. Blood dyscrasias amenable to cure or control. This includes granulocytopenia, thrombocytopenic purpura, hemophilia. Occasionally one is forced to consider transfusion for incurable leucemias and aplastic anemias for palliation. This probably should not be encouraged without excellent and individual excuses when cure or reasonable control is not possible.

4. Peripherovascular collapse with or without actual blood loss. The amount, speed, and frequency of transfusion is entirely dependent on the degree of shock and the likelihood of its return. Trauma, especially to the femur, pelvis, and abdomen, produces profound shock when there may be no apparent blood loss or hematomas. This is also true in the immediate and intermediate stages of burns. In such types of peripherovascular collapse, the problem is plasma loss, so that blood plasma or lyophile is the agent of choice while 6 per cent gum acacia solution is second choice.* In burns the patient is already suffering from red blood cell and hemoglobin concentration from plasma and water loss, and whole blood transfusion is of second or third choice. Parenthetically, it must be said that accurately calculated

*If acacia is to be used and subsequent transfusion is possibly contemplated, blood for typing and cross-matching must be taken before the acacia is given; otherwise, the blood will never be cross-matchable, because of the presence of acacia.

amounts of intravenous 5 or 10 per cent glucose with an even more accurately calculated amount of normal saline solution are of equal importance.

5. Prolonged disturbances of blood chemistry during the course of an illness involving loss of various body fluids which cannot be accurately replaced or substituted, as in biliary and intestinal fistulas, intestinal obstruction and peritonitis, gastroenteritis and colitis, empyema and lung abscess of unusual extent, weeping dermatitis, and so forth. There is apt to be an associated secondary anemia which demands transfusion, but on occasions the disturbed blood chemistry demands transfusion more than the secondary anemia would indicate. Specific medication for avitaminosis in its various forms is often valuably supplemented by transfusion. Recently blood plasma transfusion has been found superior to whole blood in many instances where the albumin and globulin ratio is disturbed. Most notable of these instances has been the promotion of rapid wound healing by the correction of this disturbed ratio in cachectic individuals.

6. Acute infections, especially of an overwhelming nature, probably should not indicate a nonspecific transfusion as such unless an actual anemia exists, since nothing specific is being accomplished and the danger of reaction is nearly 50 per cent. Immune serum or plasma may be indicated in certain instances. The practice of immunotransfusion, in which the donor receives a large dose of specific vaccine twenty-four to seventy-two hours before blood is drawn, has many advocates.

7. Methemoglobinemia such as from carbon-monoxide poisoning in which anoxemia is an acute and damaging problem may have red blood count suspensions or simply whole blood transfusions.

8. Acute hemorrhagic nephritis, especially where cure is possible.

9. Nephrosis indicates plasma transfusion and, since large amounts are not obtainable unless one possesses a large blood bank where plasma is collected as a waste product, gum acacia or the newer intravenous alimentation[52] may eventually become more practical.

CONTRAINDICATIONS

The only contraindication that can be clearly listed is any condition in which a polycythemia due to plasma and water loss exists, such as in the primary treatment of burns, polycythemia vera, cor pulmonare, and other forms of hopelessly advanced heart failure. In the presence of such findings, bleeding and rapid arterial transfusion have been suggested with the idea of producing a backwash. Certainly, if transfusion is demanded, it should be done slowly[10] and perhaps in multiple stages. At the time of such transfusions, a light liquid diet instead of solid food would seem to compensate for any load on the heart which transfusion might add. The use of strychnine and ef-

feurage (massage of the extremities toward the body) to augment venous return would seem to have a definite supplementary value. Since intravenous therapy has been elucidated, left-sided heart failure is considered in the same category as peripheral vascular collapse in general. Consequently, an extracardiac indication for transfusion, such as severe anemia, shock, etc., is augmented. This central vascular collapse adds its weight to the primary indication rather than becoming a contraindication as formerly supposed.

Generally, transfusion even in the best hands from start to finish, including technicians, laboratory facilities, equipment, materials, and the so-called ideal donor, carries a certain hazard to life, the same as even the briefest and most innocuous anesthesia, diagnostic procedure, or the most minor operation carries a definite mortality rate. Consequently, transfusion must not be taken lightly or used indiscriminately. The absolute value of the transfusion must be considered for each patient; the plea is for individualization in this as in all medical and surgical therapeutics. Transfusion is no panacea. It must not be proscribed, but it may, when properly prescribed, become the patient's "life blood."

SUMMARY

1. A brief history of transfusion has been presented, sketching its evolution to the present time.

2. The various methods of transfusion have been described. Evaluation of these has shown the consensus to favor the indirect citrate method. Stored blood and especially the bank system present the advantage of immediately available syphilis-free blood with economy of time, money, and convenience. The suggestion that stored blood is more reaction free because of lessened allergens has been made.

3. An outline of technique for the various methods has been presented with emphasis being placed on closed systems. Attention to important details in taking and giving blood with a view to lessening reactions includes avoiding defibrination, squeezing of clots in filtration, contamination, hypotonic solutions, hot and dry surfaces, heat jackets, and hot water bottles, excessive citration, citrate with hydrogen-ion concentration more than 1 away from that of blood. An evaluation of direct, indirect, and stored donors' blood, cadaver and placental blood, has been included. The drip rather than rapid or pump administration has been shown to be preferred.

4. Sources of blood have been detailed.

5. A discussion of reactions both from a clinical and an etiologic viewpoint has been detailed. Emphasis was placed on the value of observing the radial pulse at least during the transfusion of the first 100 c.c. of blood to avoid immediately fatal reactions. During the discussion of etiologic factors, careful cross-matching as well as the use of high titer typing sera was advanced as a means of obliterating

incompatibility reactions. A test was emphasized to avoid both agglutination and hemolytic reactions. Chills and other untoward effects have been shown to be partially due to faulty technique in taking and giving the blood, to impure materials, and to careless or incomplete preparation of the apparatus used. Finally, the factor of allergy of recipient for donors' blood and the avoiding of this by starving the donors to prevent lipemia and undigested proteinemia has been presented.

6. Indications were discussed with emphasis on the necessity for individualization of each candidate, being mindful not only that a certain measurable hazard attends each transfusion, but that also the type and quantity of blood to be administered must be considered as in any therapeutic procedure. This form of intravenous therapy is more effective when fitted into a definite plan of therapeutic attack preoperatively, operatively, or postoperatively rather than when demanded as an emergency heroic measure.

7. Contraindications have been discussed with special reference to associated cardiac and febrile states.

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Editorial

The Graham Anniversary

ON October 11 and 12, a number of Dr. Evarts Graham's former associates and students assembled in St. Louis to celebrate the twentieth anniversary of Dr. Graham's professorship of surgery at Washington University. Twenty-six presentations, reviewed elsewhere in this issue of the JOURNAL, were given and they are indeed a tribute to this leader in surgery. Dr. Graham has done much for surgery, by his own accomplishments and also by stimulating not only those associated with him but many others to perform original investigations. No clinician since Halsted has attracted more scientists to his clinic and laboratories for study and investigation. Dr. Graham is a prodigious worker. Since 1906, when he wrote his first article on generalized blastomycosis, he has published in all one hundred and forty-nine articles and three textbooks, one on diseases of the gallbladder and the bile ducts, one on surgical diseases of the chest, and a three-volume system on surgical diagnosis. His experimental and clinical investigations on diseases of the biliary system, cholecystography, and diseases of the thorax will always be classics. Besides these activities, he is Editor of the *Year Book of Surgery*, Editor of *The Journal of Thoracic Surgery*, member of the Editorial Board of *The Annals of Surgery*, and member of the Advisory Council of *Surgery*. He has been president of the American Society for Thoracic Surgery and the American Surgical Association, and at the present time is president-elect of the American College of Surgeons. Dr. Graham's desire to raise the standards of surgery is exemplified in his efforts in the establishment of the American Board of Surgery, of which he has been chairman since its organization.

The Graham Anniversary was appropriately completed by the inauguration of a Graham Lectureship which is to be given annually at Washington University. It is significant that this lectureship is established at a time when Dr. Graham is still in his prime. SURGERY is proud of her distinguished Editorial Advisor and joins the former and present associates of Dr. Graham in congratulating him on the enviable record which he has had at Washington University in his first twenty years as Professor of Surgery.

—*Alton Ochsner.*

Review of Recent Meetings

REPORT OF THE GRAHAM ANNIVERSARY MEETING

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(From the Department of Surgery, School of Medicine, Tulane University)

THE Graham Anniversary was held in St. Louis, Mo., Oct. 11 and 12, 1939, in honor of Dr. Evarts Graham on the twentieth anniversary of his professorship at Washington University. Two days of scientific sessions were conducted by former pupils and associates of Dr. Graham.

W. E. Adams, Chicago, Ill., presented the results of investigations on **The Relation of Intrabronchial Pressure in Minimal Lung Function and Intrathoracic Surgery.** By doing stage operations, it was possible to remove 85 per cent of a dog's lung, leaving only one remaining lobe. If a single operation was done, not more than one-half of the pulmonary surface could be removed; but by stage procedures all but 15 per cent could be extirpated. The dogs with only one lobe remaining appeared perfectly normal. In bronchietasis, in which several lobes are involved, these lobes may be removed safely in stages. It is desirable to wait several months between the individual operations.

As positive pressure is almost routine in all chest operations, Adams investigated the intrabronchial pressures which were safe. With increase in the intrabronchial pressure, there is a decrease in systemic blood pressure and apnea ultimately results. In dogs, if an intrabronchial pressure of 24 mm. or over is maintained, emphysema of the mediastinum results due to the rupture of the alveoli and extension of the air along the bronchi to the mediastinum. An intrabronchial pressure of 40 mm. produces death because of arterial hypotension. Clinically, it is occasionally observed that pneumothorax occurs on the contralateral side in thoracic operations. In such instances this is undoubtedly due to the increase in intrabronchial pressure resulting in rupture into the pleural space.

Intratracheal positive pressure is probably more dangerous than positive pressure applied through a mask. Intrabronchial pressure should never exceed 5 mm., and one should not attempt to inflate the lung at the completion of a thoracic operation but one should aspirate the air from the pleural cavity. In commenting upon this, **Dr. Graham** stated that he is of the opinion that 5 mm. was a maximum safe intrapulmonary pressure. Dr. Graham and his co-workers, too, have stopped inflating the lungs at completion of the operation, because in two cases a suppurative pneumonitis apparently was produced in this manner by forcing septic material into the terminal bronchioles. The common practice of anesthetists of increasing intrabronchial pressure by squeezing the anesthetic bag during the giving of an anesthetic is dangerous because intrabronchial pressures obtained in this way are frequently as high as 30 mm., which could easily rupture the lung; and once a break has occurred, pressures necessary to produce emphysema of the mediastinum are much less than would be necessary in the intact bronchi.

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Maurice Berck, New York, N. Y., reported results of **Roentgen Therapy for Bronchiectasis.** This therapy was begun in bronchiectasis because beneficial results were obtained by the roentgen therapy of bronchial fistulas. In six years, 85 cases have been treated with satisfactory results. The beneficial results are due to the effect of the irradiation on the inflammatory process. All cases were chronic ones in which a definite diagnosis was made and which had not responded to the ordinary forms of therapy. No acute cases were treated. The cases were classified into three groups: first, those in which the condition was really nothing but an aggravated form of bronchitis and in which the symptoms were relatively mild, consisting of cough and expectoration with seasonal variations; second, those with marked manifestations, such as clubbing of the fingers, associated with extensive lung involvement. In these cases the mortality rate was very high following lobectomy and the prognosis was bad under conservative treatment, the mortality being about 50 per cent. In the third group were those cases which were moderately severe and which were neither good nor bad surgical risks. They were not incapacitated, and there was relatively little parenchymal involvement. In the series of cases reported, x-ray was used over a period of three months and no other therapy was used. There was marked improvement in all; there was definite diminution in secretion, and subsequent pneumonitis was relieved. Clubbing of the digits also subsided. Most of the cases were relieved of the secretion although they still had bronchial dilatation. Those which were improved have remained so, some for as long as six years. About 50 per cent have been clinically free from symptoms. In few instances during the treatment there was an increase of symptoms, consisting of increased expectoration and increased fever. This rapidly subsided, however. The first group of relatively mild cases gave only a moderate response. The other two types responded well. In the moderately severe group, which is Group 3, there were 40 cases, of which 48 per cent are asymptomatic and 20 per cent are dead. In the extremely severe cases the mortality was 20 per cent, and there was asymptomatic relief in 50 per cent of the cases.

H. L. Cabbitt, Boston, Mass., discussed **Hemothorax, Its Relation to Carcinoma of the Lung.** He investigated 247 proved cases of carcinoma of the lung, of which 35 had hemothorax. Of a total of 86 hemothorax cases investigated, 39 were traumatic. Of the 47 remaining, 35 were due to carcinoma. In the 35 cases the fluid was not studied for the presence of malignant cells in 12; in the remaining cases malignant cells were found in 50 per cent. This percentage should be much higher and is at the present time, as about 75 per cent of the more recent cases showed tumor cells. The study dated back many years, however, and in many of the early cases particular care was not made to demonstrate tumor cells. In the 35 cases only 6 had bronchoscopic examinations and in 3 no tumor was seen. Bronchoscopy should be done in all cases if no malignant cells are found in the fluid. From the histologic examination of the tumor, it was suggested that adenocarcinoma of the lung gave rise to hemothorax slightly more frequently than the other types of primary malignant lesions. Metastatic lesions to the lung rarely produce hemothorax. The finding of blood in the pleural cavity in carcinoma of the lung does not necessarily mean involvement of the pleura. In 2 cases in which carcinoma cells were found in the pleural fluid there was no involvement of the pleura. On the other hand, there were 2 cases of pleural carcinoma with no blood in the pleural cavity. The prognosis in hemothorax complicating carcinoma of the lung is extremely bad as the patient is usually helpless and surgery offers nothing.

H. J. Hayden, Melbourne, Australia, discussed **Hydatid Disease of the Lung.** Hydatid disease probably is more common in the United States than is frequently thought, although it occurs much more frequently in Australia. One of the reasons

for this is the relative number of sheep per individual there. In Australia there are 14 sheep per person; whereas in the United States there are 0.3 sheep per person. Hydatid disease of the lung differs from other hydatid disease in many respects. About 70 per cent of all hydatid disease of the body occur in the liver and only 10 per cent in the lung. About 1:300 of all hospital admissions in Australia are for hydatid disease of the lung. Generally the subpleural portion of the right base is the most frequent site of involvement. Very seldom do complications develop, and, in contradistinction to hydatid disease of the liver, calcification of the cyst is infrequent. Daughter cysts seldom develop and seldom is the material inspissated. The reason for this is that the duration of the hydatid disease of the lung is relatively short. It is usually coughed up or may become infected, which results in death of the parasite. If the process extends to the pleura, however, the infection may be widespread. Generally, the lesion is primary and single. The x-ray shadow does not give a clear-cut edge but is rather fuzzy. Eosinophiles are usually present. Twenty-five per cent of the hydatid cysts are latent, and 33 per cent become manifest when a superimposed infection occurs. The most frequent symptom is hemoptysis. Of diagnostic importance is the Cassoni intradermal test which is positive in 90 per cent of instances. The complement fixation test is of little value except in the postoperative case in which it is possible to determine whether there is persistence of the hydatid disease. Treatment consists of thoracotomy, evacuation of the cyst contents, and removal of the cyst wall, followed by primary closure of the wound. If the case becomes secondarily infected, it should be treated as a lung abscess. A hydatid cyst should not be aspirated because of the danger of rupture. When the cyst ruptures into a bronchus, the treatment consists of postural drainage.

Byron S. Francis, Seattle, Wash., described a case of marked sclerosis of the lung resulting from radiation therapy. The patient was a 71-year-old female who had had a mammectomy for carcinoma of the right breast and who had been given intensive x-ray therapy. Two months after the beginning of the therapy, a dry cough and a slight pyrexia developed. Six months after the beginning of the treatment there were a few shadows in the right hemothorax which progressed, resulting in marked retraction of the mediastinum towards the affected side. A year after the beginning of the treatment, the cough became much worse and the patient was incapacitated. Bronchoscopy showed marked deviation of the trachea to the affected side with kinking of the upper lobe which interfered with emptying of the bronchus. An artificial pneumothorax was produced. An extremely high intrapleural pressure was present, so high in fact that it was impossible to determine it. Immediately after the production of the pneumothorax, the cough was greatly relieved and the patient was able to sleep for the first time. She was much improved as the result of the artificial pneumothorax.

W. B. Ehrlich, Newark, N. J., reported a case of brain tumor of known twenty-three years' duration which was treated successfully by operation. In 1914, the patient had had headaches and diminution in vision. In 1916, a temporofrontal decompression was done. One month later, 20 c.c. of fluid was removed from the right cerebellum. In 1922, a cerebellar cyst was opened and the wall painted with picric acid. The patient was free from pressure symptoms until December, 1937, when he became blind in his right eye and developed optic atrophy in his left eye. Lumbar puncture revealed yellow fluid. He was reoperated upon by Ehrlich, who found a cyst involving the entire right cerebellar lobe containing a mural tumor, measuring 5.5 cm. in diameter. The tumor was removed and the patient was subsequently treated with deep x-ray. All cerebellar signs cleared up. Probably as the result of the operation in 1922, a fistula developed which permitted cystic fluid to escape into the subarachnoid space from which it was absorbed.

I. Y. Olch, Los Angeles, Calif., discussed the **Menopausal Age in Women With Cancer of the Breast.** Three hundred and fifty cases of breast carcinoma were studied and it was found that of this number 186 (55 per cent) had menstruated beyond 50 years of age. If menstruation continues past 47 to 48 years, then artificial menopause should be produced. Normally, only 9 to 12 per cent of women menstruate past 50 years of age. Young women with carcinoma of the breast should have an artificial menopause produced by irradiation after the breast has been irradiated and removed. Olch emphasized the importance of ovarian secretion in the growth of mammary lesions.

E. C. Padgett, Kansas City, Mo., discussed the **Calibrate Intermediate Skin Graft.** By means of an ingenious device, which Dr. Padgett has constructed, it is possible to cut skin grafts any size, any shape, and any thickness and from almost any place. Generally, skin grafts vary from 0.01 to 0.0042 inch in thickness. The machine consists of a half-cylinder to which is attached a knife which can be set to cut at any desired thickness. The surface of the drum and the skin from which the graft is to be taken are painted with rubber cement. By rotating the drum, to which the skin adheres, any desired thickness of skin can be cut. By means of this machine it is possible to cut deeper grafts and yet leave sufficient of the deeper layers of the skin at the donor site to secure regeneration. Such a graft has the advantages of a full thickness graft without its disadvantages.

W. D. Thompson, Philadelphia, Pa., reported on preliminary experiments in tetanus. Whereas phenol has been thought to be of value in treatment of tetanus, Thompson found that phenol intrathecally was distinctly detrimental and that more animals died if antitetanic serum containing phenol was used than if antitetanic serum alone was used. This is because of the destructive action of phenol on the central nervous system. Sixty per cent of tetanus toxin given to animals is fixed within six-hour periods, but, if 182 times a neutralizing dose of antitoxin is given, the experimental animal will survive. If the antitetanic serum contains phenol, it should not be given intrathecally. The intravenous method of antitetanic serum is the most efficacious.

Minas Joannides, Chicago, Ill., described a new axillary approach with a muscle-splitting incision for extrapleural pneumolysis. The operation is done under local analgesia through an oblique incision which extends from the second rib in the anterior axillary line downward and posteriorly to the fifth rib in the posterior axillary line. Either the third or the fourth rib is resected over a distance of about 8 to 10 cm. The pleura can then be stripped readily from the thoracic cage. The advantage of the axillary approach is that it is possible to visualize the posterior portion of the thorax as well as the anterior and it produces no scar and no deformity. After closure of the wound, Joannides recommends leaving a catheter in place and filling the cavity with saline solution, and refilling with saline solution daily for a week, following which air is introduced and the catheter removed.

Harry C. Ballon, Montreal, Quebec, discussed the effect of sulfanilamide on the tubercle bacillus. The growth of tubercle bacilli in cultures is greatly retarded by high concentrations of sulfanilamide, and sulfanilamide is of value in decreasing the number and size of tuberculous lesions in guinea pigs. Just what the clinical effect of sulfanilamide will be, Ballon did not attempt to state. Experiments demonstrate that sulfanilamide has inhibiting effects on tubercle bacilli both in vitro and in vivo experimentally.

Alton Ochsner, New Orleans, La., discussed the role of vasospasm in thrombophlebitis. In animals a chemical thrombophlebitis in localized segments of the femoral vein was produced by injecting sodium salicylate into an isolated segment of the vein. Immediately after the injection of the sclerosing agent into the segment of vein, arteriorly pulsations in the homolateral foot were greatly diminished. This did not occur if the experiments were performed in an animal in which a previous lumbar sympathectomy had been done. The vasoconstricting influence was also stopped by the perivenous injection of novocain. It is obvious, therefore, that there originates in a thrombophlebitic vein vasoconstrictor impulses which are carried over the sympathetic nervous system and which produce marked spasm of the homolateral arterioles. Clinically, thrombophlebitis presents the same features. The extremity is cold and the arteriolar pulsations are greatly diminished. The treatment of thrombophlebitis clinically consists of the injection of the lumbar sympathetic ganglia on the affected side with 1 per cent novocain. In 17 cases so treated there was immediate relief of pain in all instances. There was a rapid subsidence of fever and edema. Convalescence was greatly shortened, lasting only for a week or ten days. Novocain injections are made daily, injecting 5 c.c. of 1 per cent novocain into the first, second, third, and fourth lumbar ganglia daily as long as the patient has fever.

J. W. Gale, Madison, Wis., presented the case of a 39-year-old male with a cystic tumor attached to the pericardium which was detected accidentally during fluoroscopic examination. The patient's only symptom was epigastric distress. The tumor was removed by thoracotomy. It probably originated as a pericardial diverticulum with subsequent closure of the communication between the pericardium and the cyst. A second case was that of a male, 38 years of age, in whom a diagnosis of tumor of the right lower bronchus was made on the basis of atelectasis at the right lower lobe. Two bronchoscopies showed chronic inflammation. A total pneumonectomy was done and a tumor involving the right lower bronchus, which apparently was a chondroma, was found. Gale advocated draining the mediastinum in cases of total pneumonectomy by making a long tunnel subpleurally to the posterior thoracic wall. He believes that in this way mediastinitis can be prevented.

Discussing this, **Dr. Graham** said he approved of total pneumonectomy in cases in which apparently the lesion is a benign tumor because so frequently the bronchoscopic removal of the tumor removes only that portion of the tumor which projects into the bronchus and many times a much larger portion of the tumor is left behind. Frequently, too, these tumors subsequently become malignant. **Dr. Nathan A. Womack,** St. Louis, Mo., discussing the lesion in this case, was of the opinion that it was of the mixed tumor type which he and Dr. Graham had described.

Warren H. Cole, Chicago, Ill., described **The Effect of Experimental Partial Obstruction of the Cystic Duct.** Not infrequently one sees cases presenting symptoms of cholecystic disease in which at operation the only discernable abnormality is a marked obstruction of the cystic duct. The obstruction may be due to many causes. Heister's folds may have a transverse arrangement and thus obstruct the flow of bile. Cole attempted to reproduce Heister's folds in gall bladder of dogs by forming a flap of mucosa near the cystic end of the gall bladder. In control animals a similar flap was produced in the fundus. In other experiments a tuck was taken in the cystic duct. In the animals with the flap near the cystic duct, the gall bladder appeared normal at the end of three months, but at the end of seven months there was a definite cholecystitis which consisted of fibrosis and edema. Simple ligation of the cystic artery and the lymph duct also produced changes in the gall bladder. Cole is of the opinion that many cases of cholecystitis may result from chronic obstruction of the cystic duct.

Lyman Brewer, Ann Arbor, Mich., discussed the **Treatment of Postoperative Pulmonary Complications With Special Reference to Intratracheal Suction.** At the University of Michigan postoperative intrabronchial suction is used extensively. About 70 per cent of all postoperative pulmonary complications are the result of atelectasis or bronchial aspiration. Aspiration of infected secretions and presence of the viscous plug are most important in the formation of these conditions. Later pneumonitis and possibly pulmonary abscess develop. Unconsciousness predisposes to the retention of secretion. Asthenia, pain in the wound, inspissation of secretions as the result of dehydration, and extensive thoracic decostalization prevent expectoration. Brewer emphasized the importance of preoperative emptying of the tracheobronchial tree by coughing or bronchoscopy in patients with considerable secretion. In those cases in which there is considerable secretion it is best to perform the operation in the Trendelenburg position. In operations on the upper abdomen in which there is considerable secretion, postoperative bronchoscopic drainage should be done. Prolonged unconsciousness postoperatively is to be prevented, and the patient should be encouraged to cough. Carbon dioxide and oxygen inhalation are permissible, provided the patient coughs afterwards; but, if the patient is in an upright position, there is some danger of forcing the secretions into the lower lobe. Intratracheal suction is indicated in the presence of a wet, nonproductive cough, in unexplained cyanosis, and in unexplained and prolonged unconsciousness. First, an intratracheal catheter and active suction should be used. If this fails, then bronchoscopy should be used. The latter is indicated in those cases in which the secretion is particularly thick, in which there is atelectasis, and when the catheter fails. In 1,851 major operations performed at the University of Michigan, of which 451 had preoperative pulmonary lesions, there were only 63 postoperative pulmonary complications, results which compare very favorably with the incidence of postoperative complications elsewhere.

W. B. Gnagi, Jr., Monroe, Wis., discussed the advisability of performing gastrectomy in cases of peptic ulcer. In cases of peptic ulcer which resist medical therapy, subtotal gastrectomy should be done. Gnagi prefers high resection with anterior colic anastomosis.

Robert Elman, St. Louis, Mo., discussed the **Intravenous Administration of Amino Acids.** He emphasized the inadequacy of transfusion to replenish plasma proteins in the presence of hypoproteinemia. The amount of blood given in a transfusion contains approximately 17 gm. of proteins, and, even if two transfusions are given daily, there is hardly enough to maintain protein balance. Proteins are best given in the form of amino acids. As the cost of the synthetic amino acids is prohibitive, the solution of the problem is best met by hydrolyzing proteins. Elman uses the hydrolyzed casein which contains all of the eleven essential amino acids. They should be given slowly because otherwise the patient is likely to have a reaction. Elman has used this form of therapy in 25 patients and the relief of hypoproteinemia has been quite dramatic, although in some cases the results have not been as gratifying.

L. C. Barrett, Sacramento, Calif., gave a résumé of the early history of California and presented facts concerning the San Francisco bridge.

The afternoon of the last day was given over to short presentations by members of the Washington University surgical staff. **Dr. Graham** discussed **Chest Surgery Then and Now.** There is need for changing the common conceptions of chest surgery. Until relatively recently, thoracic surgery was thought to carry an extremely high mortality and to be associated with considerable deformity. Such is

no longer true. Six years ago, mortality rate from lobectomy was 30 per cent, and only 50 per cent of those who recovered from the operation were relieved. Now this is considerably different. In the past 76 consecutive lobectomies for bronchiectasis, the mortality was less than 5 per cent and less than that for acute appendicitis at the Barnes Hospital. Pneumonectomy is also successful. The first successful pneumonectomy ever accomplished was performed by Dr. Graham in April, 1933. The patient is still living and well. Two cases were presented. One was a patient who apparently originally had a benign tumor which later became malignant. In this instance, the tumor had involved the wall of the trachea, necessitating excision of a portion of the trachea. There was considerable difficulty closing the trachea, but this was finally accomplished. As the patient had had a trauma eight years before, it was felt that possibly the trauma might have been a factor in producing malignant change. The second case was a pneumonectomy which was done only eight days previously. One of the greatest difficulties in treatment of bronchiogenic carcinoma is that they are seen relatively late, and another factor which is responsible for the difficulty in saving these individuals is that the disease occurs in older persons.

Brian Blades discussed 76 consecutive cases of bronchiectasis treated by lobectomy at the Barnes Hospital with a mortality of less than 5 per cent. He emphasized the importance of careful preoperative localization. In the cases in which there is an involvement of the left lower lobe, the lingula of the upper lobe was involved in 53 per cent. In those cases in which the right lower lobe was involved, the lingula of the middle lobe was involved in 51 per cent. There is little increase in operative risk following the removal of the lingula. Preoperative and postoperative bronchoscopy are of great value in preventing postoperative complications. Since they have been using this routinely, there have been no deaths from postoperative pneumonia. In 2 cases, apparently with pneumonia, the lesion responded to sulfapyridine administration. In determining the involvement of the lingula, it is important to take oblique roentgenograms following introduction of lipiodol. An ordinary anteroposterior roentgenogram is of no value. In 18 patients individual ligation of the hilar structures to involved lobe was done. This is more time-consuming but is of value as 7 of the 18 did not develop empyema. The remaining 11 developed a simple empyema. The advantage of this is that the convalescence is greatly shortened. The average hospital stay was three and one-half weeks, the shortest eighteen days. There was no bronchial leak in any of them. It cannot be done, however, in all cases.

Nathan A. Womack described mixed tumors of the lung which he believes originate from the pulmonary fetal anlage. Many of them resemble fetal lung tissues. Many congenital anomalies of the lung are possible, varying from congenital cystic disease to aberrant rests which may become malignant. When the mesenchymal elements outgrow the epithelial elements, the tumor is a chondroma or chondrosarcoma. Occasionally, a primary tumor of the lung is so small that it can hardly be diagnosed and yet the regional lymph nodes will have metastases. Many tumors which appear benign bronchoscopically are actually malignant in that they invade. Womack compared these to black moles of the skin and stressed the importance of not removing them bronchoscopically and emphasized that in such cases a pneumonectomy should be done.

Peter Heinbecker discussed the development of the collateral circulation of the heart by the production of intrapericardial adhesions. Experimentally, he produced pericardial adhesions by introducing into the pericardium sodium morrhuate aleuronat, and corborundum sand. He was able to develop collaterals through the

adhesions and was of the opinion that there was no interference of cardiac function as determined electrocardiographically as the result of the adhesions.

Vilray P. Blair discussed cancer about the face and neck. Early lesions about the lip should be treated as they are frequently premalignant lesions. Radiation scars should be removed. The tumor which has an excessive outward growth is less malignant than that which penetrates deeply. It is never possible to say when regional lymph glands are involved. They may become apparent ten to fifteen years after the original lesion is removed. When the buccal gland is involved, the mandible frequently becomes involved. Because of the impossibility of determining when the regional glands are involved, Dr. Blair is of the opinion that a block dissection of the neck should be done in all cases of carcinoma of the face. In extensive infiltrating tumors of the face, irrespective of what is done, most, if not all, patients will die of malignancy within ten years. Blair does not believe that one can rely upon differentiation between squamous- and basal-cell carcinomas as an aid in prognosis.

Ernest Sachs discussed 25 cases of choked disk without brain tumor. The symptoms in these cases were headache and visual disturbances. The only positive finding was bilateral choked disk. The condition occurred more frequently in women. In none of the 25 cases he investigated was there an arterial hypertension. Some of the patients had mild infection, but others did not. Sachs believes that a decompression should be done in order to save sight. One patient had an accidental hyperpyrexia and was greatly benefited. Others were given heat therapy with less dramatic results. The diagnosis is made by the absence of positive findings with air studies.

Duff Allen reported the results obtained in Addison's disease by implanting pellets of pure hormonal (adrenal cortical) substance subcutaneously. Usually the lumbar area is chosen as the site for implantation. To determine the rate of absorption, the weight of the pellet was carefully determined before it was embedded and determined after it was removed. A case was cited which had resisted all forms of therapy, but which was relieved by the subcutaneous implantation of adrenal cortical substance. There was an increase in blood pressure, blood chlorides, and weight. In this case it was determined that the patient used 0.3 mg. each day. Enough of the substance was implanted into the patient to supply him for a year. In those pellets which were removed and examined histologically, it was found that a fibrous capsule developed around it but that there was little reaction aside from this.

Leonard Furlow reported 4 cases of spontaneous intracerebral hemorrhage, 3 of which occurred in hypertension, which were treated by surgical removal of the blood. All had increased intracranial tension. The operation should be reserved for a relatively small group of cases. Of the 4 cases reported, evacuation of the clot resulted in the relief of all symptoms. In a patient with an intracerebral hemorrhage, who does not improve and who has an increased intracranial tension, air injection should be done. If the clot is large, then one is justified in evacuating the clot surgically.

A banquet was tendered Dr. Graham the evening of the second day which was attended not only by his former students and associates but also by many of the medical profession of St. Louis. Four talks were given. **Dean Philip A. Shaffer** discussed Dr. Graham and Washington University. **Dr. Allen D. Whipple** discussed Dr. Graham and American surgery. **Dr. J. D. Haydun** discussed Dr. Graham and international surgery and **Dr. Malvern D. Cloptom** discussed Dr. Graham and medical education.

Book Reviews

Problems of Ageing: Biological and Medical Aspects (A Publication of the Josiah Macy, Jr., Foundation). Edited by E. V. Cowdry, M.D. Cloth. Pp. 758, with 121 illustrations. Baltimore, 1939, Williams and Wilkins Company. $10.

This remarkable volume has been made possible by the collaboration of twenty-six authors under the sponsorship of the Josiah Macy, Jr., Foundation.

The only economic touch given the problem of ageing is to be found in the introduction written by the philosopher John Dewey. The chief objective of the undertaking has been to record and correlate the factual data available relating to ageing of various organs and systems of tissues. In consequence an astounding bit of information has been gotten together in one volume on the physiology of ageing processes. He who examines the volume for definite answers to many questions concerning the nature of the ageing process will be disappointed. No one can read or study the volume, however, without experiencing a feeling of gratitude to the editor and his contributors for having made this interesting compilation available.

The monograph has essayed to deal with pathologic processes only so far as they are the direct product of the ageing problem. In a forward looking monograph such as this, one might reasonably have expected to find some discussion of euthanasia with reference to the social order and the ageing process. Yet, such a discussion belongs more properly perhaps in a sociological economic study of the end effects of diseased processes.

No encouragement is lent in this monograph that the span of life will be extended. The biblical three score and ten remains yet the measure of old age. The usual infirmities of ageing process apparently are still such that the contention of the ninetieth psalm holds yet, today; namely: "And if by reason of strength they be fourscore years, yet is their strength labour and sorrow."

This book should appeal to a wide audience of medical readers. It can be recommended enthusiastically as a source of fascinating and instructive reading. It should prove a splendid book of reference and deserves serious study.

Experiences in the Management of Fractures and Dislocations (Based on 4,390 Cases). By the staff of the Fracture Service of Massachusetts General Hospital, Boston, under the general editorship of Philip Wilson, M.D. Leatherette. Pp. 1,036, with 1,419 illustrations. Philadelphia, 1938, J. B. Lippincott Company.

This is probably one of the best documented monographs detailing the entire experience of one clinic over a period of years in the management of fractures that has been published. The well-integrated teaching and service features of the fracture staff of the Massachusetts General Hospital have long been known. As a matter of fact, their experience and plan of organization have served as a stimulus for many a municipal hospital in a large metropolitan area to emulate their example. Those interested keenly in fracture therapy, therefore, will welcome this book in which the experience of the Massachusetts General Hospital clinic is set forth.

The mode of management of every case is detailed, including a statement of the eventual anatomical and functional results as well as the economic capacity of the patient. Much of the text is occupied by material of this sort, probably far more than its importance justifies.

However, the authors do not essay to encompass the whole field of fractures and dislocations in a systematic manner. Their objective has been to relate the methods they have used and their own experiences. Much of the material in the series dates back to the early and middle twenties. In consequence, the greater emphasis on skeletal traction and mechanical appliances to maintain reduction which has come generally into fracture treatment in the last few years is missing in this book. Emphasis has properly been placed on the nonoperative methods of treatment. The modern treatment of fractures of the anatomical neck of the femur had its beginnings in the Massachusetts General Hospital and Smith-Petersen's methods are described well. Yet, the open method of treating such fractures is favored over the present more commonly employed closed reductions.

Whereas the text cannot be regarded as a systematic treatise on the management of fractures and dislocations, it is a significant contribution to fracture therapy. It deserves to be widely read by those who interest themselves in the surgery of skeletal trauma.

Functional Disorders of the Foot, Their Diagnosis and Treatment. By Frank D. Dickson, M.D., and Rex L. Diveley, M.D. Cloth. Pp. 305, with 202 illustrations. Philadelphia, 1939, J. B. Lippincott Co. $5.

The authors have compiled a modern working manual suitable for orthopedic surgeons and other physicians interested in the treatment of ailments of the human foot. This volume covers in a satisfactory manner the evolutionary development and the anatomy and physiology of the human foot and the examination and treatment of conditions causing symptoms. A discussion of the proper types of shoe for feet of various types and ages is given. The symptoms and types of foot trouble are discussed according to their age groups, such as childhood, adolescence, and adulthood.

The more useful types of operative procedures used by orthopedic surgeons in the treatment of foot disorders remedied by surgery are discussed and presented in a concise and clear manner with ample illustrations to clarify the text.

The work is simply written, but it is adequate to cover all the necessary phases of treatment of foot conditions. Its completeness should recommend it to those who are interested in a text of facts in the care of ordinary foot disorders.

Peripheral Vascular Diseases: Diagnosis and Treatment. By William S. Collens, M.D., and Nathan D. Wilensky, M.D. Cloth. Pp. 243, with 77 illustrations. Springfield, Ill., 1939, Charles C. Thomas, Publisher. $4.50.

The practicing physician will find a wealth of valuable information conveniently available in this book. It is fitting that, with the increase in the interest in the field of peripheral vascular disturbances during the past fifteen years, a monograph should now appear to correlate all the results of the recent investigations which are concerned with the clinical aspects of the subject. As in most monographs a certain amount of objectiveness is lacking, especially in those chapters having to do with treatment. Intermittent venous occlusion (the authors' own contribution to the treatment of peripheral vascular diseases) is

discussed in detail and given a prominence to other recognized forms of treatment that is unusual. In other respects the book is remarkably complete and orthodox. Few subjects are discussed exhaustively, but all important practical points are clearly set forth. For those readers who may desire a more comprehensive knowledge of the subjects dealt with in the text, fairly extensive bibliographies are appended at the end of each chapter.

Of particular value to the practitioner is an excellent chapter on methods of examination, in which emphasis is placed on those methods by which an early diagnosis can be made. Simple as well as complicated procedures are described.

It is well that our attention should be called to the possibilities of intermittent venous occlusion. The physiologic basis of this procedure is sound. An entire chapter has been devoted to a detailed description of its use in clinical cases. The results of this method of treatment in selected cases as shown and described in the chapter on "The Treatment of Thrombo-angiitis Obliterans" are truly remarkable.

Many excellent photographs and diagrams are interspersed throughout the 243 pages of the book. A well-arranged table of contents and index will be particularly valuable for reference. This is by no means the best book that will be written on the subject of peripheral vascular disease, but it is the best that has appeared to date. It is well worth its cost to all who are interested in the field that it covers.

Textbook of Surgery. Edited by Frederick Christopher, M.D. Cloth. Pp. 1,695, with 1,381 illustrations. Philadelphia, 1939, W. B. Saunders Company. $10.

This book has 1,695 pages and 1,381 illustrations. It has been written by 188 authors. This new edition brings the work up to date with the revision of old and addition of new chapters. Every chapter is written by an author selected for his familiarity with his subject. It is well written, well arranged, and remarkably complete for a single volume work on general surgery. As a textbook it is undoubtedly the most complete in the field at present. It is not only of value as a textbook for students, but it is very useful as a ready reference book for the practitioner. It is recommended without reservation by the reviewer.

Diagnosis and Management of Diseases of the Biliary Tract. By R. Franklin Carter, B.S., M.D., F.A.C.S., Carl H. Greene, A.B., Ph.D., M.D., F.A.C.P., and John Russell Twiss, A.B., M.D., F.A.C.P. Cloth. Pp. 432, with 84 engravings and 6 plates. Philadelphia, 1939, Lea and Febiger. $6.50.

One would expect in a volume of 417 pages devoted entirely to considerations of the biliary tract that a satisfactory discussion of the physiology of this system would be found. This is not the case. Chapter I, which is entitled "Physiology of the Gall Bladder," deals in a little over four pages with only the motor functions of the extrahepatic bile passages. The authors stress the fact that careful investigation and management of every biliary case are essential. The illustrations are excellent and the diagrams profuse. The reviewer, however, believes that the various sections of the book are not integrated as they should be. This is due to the fact that the volume consists of a series of papers on various aspects of biliary tract disease with major emphasis on the gall bladder rather than of a correlated story. Each chapter has its own bibliography which is a useful and important part of the book, even though in numerous instances names are misspelled and where joint authorship is concerned but a single author is often mentioned. It seems

hardly possible that a volume on diseases of the biliary tract could be published during this year without mentioning the use of vitamin K and bile salts in controlling the hemorrhagic tendency of the jaundiced patient. The surgical section reads more clearly than do the other portions of the book. As a record of the experience of a single clinic over a period of years it is an interesting volume, but as a contribution to our knowledge of biliary tract disease it adds very little.

Office Gynecology. By J. P. Greenhill, M.D. Pp. 406, with 106 illustrations. Chicago, 1939, The Year Book Publishers, Inc. $3.

This volume of some 400 pages contains a wealth of information. It meets a real need for the general practitioner who can here find various office procedures for the treatment of gynecologic conditions well described. Several procedures, such as tubal sterilization by intrauterine coagulation and the destruction of Bartholin's gland abscesses with the cautery, are not generally accepted as office procedure.

The reviewer recommends the book highly.

Textbook of General Surgery. By Warren H. Cole and Robert Elman. Ed. 2. Pp. 1,031, with 559 illustrations. New York, 1939, D. Appleton-Century Co., Inc. $8.

In this second edition the authors have succeeded in accomplishing a real revision. They have found room for a large variety of new material without increasing by a single page the size of the book. The textbook is what it purports to be, an excellently illustrated, not too detailed survey of the general surgical field for student use. It retains its approach to the clinic from the direction of pathology and pathologic physiology. It is to be commended for its omission of operative detail.

The task of the authors of a textbook of surgery is exceedingly difficult. The enormous size of the field, the variations in surgical opinion (often diametrically opposed), the vast literature, the rapid spread of knowledge, and the limitation of the experience of any group of surgeons, all these form a complex which the authors must resolve in producing a consistent, relatively brief, and readable text to include established and apparently established truth, as well as important controversial matter with due attention to the reasons of both protagonists. The problems of selection and emphasis are huge. By the same token the task of the reviewer of a textbook of surgery is not easy. By the nature of the situation the excellencies of such a book are apt to be general, and its defects specific. Keeping in mind the fact that any textbook ultimately reflects the particular personal bias of its authors in habits of thought and methods of attack, one may perhaps be justified in pointing out minutiae wherein in the reviewer's opinion improvement in teaching value might be attained. For reasons of space these critical remarks cannot be considered inclusive.

The chapter on shock and hemorrhage deserves a thorough revision. It is confusing to the reviewer and in his opinion would utterly confound the beginner. Part of this is unquestionably due to a loose or double use of the word "primary." "Primary Clinical Causes of Shock" is the heading of a group of paragraphs discussing hemorrhage, tissue trauma, and burns as differentiated from "Secondary or Contributing Causes of Shock," such as cold, anesthesia, etc. In one of the included paragraphs under the former heading is the statement that the "effect

of burns is usually manifested at once and hence is a good example of primary shock.'' Although one may with considerable assurance question the acceptability of the quoted sentence on the basis of the work of Blalock, Phemister, and others, the point here is that the word ''primary'' has been applied both to the cause and the effect within the limits of a single page. A similar lack of clarity can be found in other portions of the discussion. For instance: ''Pallor, coldness and perspiration are the same as those produced by vasoconstriction (sympathetic stimulation)'' (p. 290). It is the reviewer's conception that these symptoms in ''shock'' are in fact the result of sympathetic stimulation which is an integral part of the disturbed physiologic processes of the condition. Again, ''in hemorrhage the reduction in blood volume is obviously equal to the amount of the lost blood'' (p. 295), a statement that omits any consideration of the body's fluid reserves. The subject of shock is perhaps the most difficult, unsettled, and controversial with which the authors have to deal. It is the reviewer's belief that an entirely new treatment would bring this chapter up to the general excellence of the volume.

A few more criticisms of a minor nature may be made. For instance, the question may be raised whether Figure 68 *C* (p. 128) adequately diagrams the operation of débridement to illustrate the importance of attempting to avoid contamination of the new surgical wound from the old accidental wound. One may challenge the careless statement on the following page that ''epithelial edges unite only by deposition of scar tissue.'' According to most modern teaching, one of the chief advantages of silk for buried suturing is the fact that it necessitates for successful use a regard for gentle tissue handling, for the absence of tension, for point ligature rather than mass ligature, in fact for all the finer technical niceties that make for success in surgery and that can be, and often are, neglected when catgut is employed; yet this advantage is not listed among the other advantages of silk (p. 135). The time element as an important factor in the decision for or against operative treatment in established peritonitis is entirely omitted (p. 701). Aspiration is presented as helpful in the diagnosis of subphrenic abscess in spite of a growing opinion to the contrary (p. 704). The ''eunuchoid characteristics'' sometimes seen with cryptorchidism are ascribed to a failure of the internal secretory function of the undescended testis, rather than suggesting that both eunuchoid qualities and cryptorchidism may be the result of a pituitary dysfunction (p. 982).

The reviewer does not desire to be captious in his comments. It is essential, however, that the first steps of the student in surgery be guided with exceptional care. It is believed that consideration of these specific examples and others not here recorded might enhance the excellence of an already generally excellent work, in which the major virtues of selection and emphasis are unimpeachable.

The Rockefeller Foundation—Annual Report 1938. Paper. Pp. 515, with 29 illustrations. New York, N. Y., 1939, The Rockefeller Foundation.

Few private philanthropies have contributed as generously as has the Rockefeller Foundation to the progress of medical science and the promotion of social progress. The 1938 Report contains information as to the work of the Foundation in varied fields: public health, medical science, natural science, social sciences, the humanities, health in China, and special research aid for deposed European scholars. The report of the International Health Division unfolds unusually fascinating work with some of the most important of the infectious diseases, including yellow fever, malaria, and influenza. Special note should be made of the program for vaccination against yellow fever and the attempt to limit the spread of *Anopheles gambiae,* an extremely dangerous vector of malaria which has recently been transported from Africa and become established in certain parts of South

America. Exclusive of the work of the International Health Division, over five and one-third million dollars were spent during the year in the interest of medical sciences and over $2,800,000 for natural sciences. Only by actual reading of the titles of the various study projects that have been aided by the Foundation totaling almost 400 in these fields, the social sciences, and the humanities, can one begin to comprehend the scope of the work of this philanthropy.

Infections of the Hand. By Lionel R. Fifield, F.R.C.S., England. Ed. 2 by Patrick Clarkson, F.R.C.S., England. Cloth. Pp. 167, with 57 illustrations, including 8 plates (2 colored). New York, N. Y., 1939, Paul B. Hoeber, Inc. $3.25.

Since Kanavel's classical monograph on infections of the hand, most authors have felt apologetic in presenting the subject. In the preface of both editions of their book, Mr. Clarkson and the late Mr. Fifield state that there is need for a smaller and simpler book on hand infections for students, house surgeons, and practitioners. To keep the size of their book within moderate limits, detailed accounts of anatomical investigations have been omitted. Even considering this, the whole subject is adequately and thoroughly discussed. One may not agree with some of the types of incisions described; for instance, that for abscess in the midpalmar space (page 84) and that for infection of the thenar space (pages 86-88). The illustration of the wrong type of incision to make in hand infections is appropriate and effective (page 112).

In the main, treatment is well described; chemotherapy is mentioned. However, Bier's hyperemia is little used in this country for infection of the extremities. Under special infections, the use of antiserum and ultraviolet irradiation is not mentioned in the treatment of erysipelas. As to the use of arsenicals in the treatment of infections due to Vincent's organisms (human bites, page 38), the effectiveness of this therapy in human bites, as well as lung abscess, is based upon hearsay rather than factual evidence.

For its size there is no better book written about hand infections. The illustrations are clear. The index is adequate. All in all, the author has done a creditable job with this edition.